Arnold Schwarzenegger
Governor

SUPER EFFICIENT GAS WATER HEATING APPLIANCE INITIATIVE

PIER FINAL PROJECT REPORT

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Super Efficient Gas Water Heating Appliance Initiative is the final report for the Super Efficient Gas Water Heating Appliance Initiative Project (contract number 500-05-010), conducted by Valley Energy Efficiency Corporation. The information from this project contributes to PIER's Buildings End-Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/pier or contact the Energy Commission at 916-654-5164.

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Abstract

This phase of the Super Efficient Gas Water Heating Appliance Initiative (SEGWHAI) researched the processes necessary to fill the market gap between standard efficiency natural gas water heaters and higher-priced more efficient units.

Using market research, stakeholder input, and other research tools, the initiative developed performance-based energy factor tier criteria for the manufacture of advanced efficiency water heaters. The tier criteria also call for the reduction of emissions of oxides of nitrogen to levels required by the South Coast Air Quality Management District Rule 1121. The two-tier criteria suggest an energy factor of 0.70 for Tier 1 non-condensing units and energy factor 0.82 for Tier 2 condensing units. These criteria have potential to reduce natural gas consumption and carbon dioxide emissions by between 17–29 percent.

The initiative recommends that the criteria be implemented by energy efficiency programs, included in revisions to the federal tax credit for water heaters and used by ENERGY STAR** for natural gas storage water heater standards. The program also recommends a prototype phase to develop advanced efficiency products, future work to understand hot water draw patterns, continued efforts to establish best practices for hot water distribution systems, and revision of energy factor test procedures.

Keywords: Super Efficient Gas Water Heating Appliance Initiative, SEGWHAI, hot water, gas water heater, natural gas, energy efficiency, Energy Factor, therm, oxides of nitrogen, NO_X, carbon dioxide CO_2, South Coast Air Quality Management District, SCAQMD, Rule 1121, ENERGY STAR*, condensing, non-condensing

Executive Summary

Background

Widely used throughout California and the United States, gas water heaters emit carbon dioxide (CO_2) and oxides of nitrogen (NO_X)—and therefore contribute to global climate change and poor air quality. Efficiency improvements to baseline gas storage water heaters over the past two decades have been relatively minor. However, the replacement rate of close to a million units per year in California alone creates the potential to rapidly improve gas storage water heating efficiency.

Purpose

The Super Efficient Gas Water Heating Appliance Initiative (SEGWHAI) aims to improve the efficiency of gas water heaters to reduce gas consumption, cut household costs, and reduce environmental impacts. The scoping phase of SEGWHAI, documented in this report, recommended technical specifications, stakeholder activities, and a plan for implementing strategies to improve the efficiency of gas water heaters. This project also promoted the development, manufacture, sales, and installation of affordable, cost-effective, high efficiency storage gas water heaters for the residential market. These activities helped to ensure that efficient, cost-effective units that reduce annual gas consumption by 17–29 percent could potentially enter the market in 2007.

Objectives

- Establish a steering committee of project stakeholders to develop criteria for super-efficient residential storage gas water heaters for replacement and new construction applications.
- Conduct steering committee meetings to establish consensus and build understanding among stakeholders. Support steering committee activities through project-developed research, outreach materials, and a communications website.
- Develop the criteria for super-efficient water heating appliances.
- Produce a final report that establishes the rationale and foundation for the proposed criteria.
- Make recommendations for future work and initiatives regarding residential storage natural gas hot water heaters.

Project Outcomes

SEGWHAI achieved the following outcomes:

- Convened five collaborative stakeholder steering committee meetings with more than 45 participants representing North American water heater manufacturers, utilities, government, efficiency advocates, and trade associations.

- Developed a two-tier, performance-based, energy efficiency criteria for natural gas storage water heaters and a supporting report that established the rationale and foundation for the proposed criteria.
- Established SEGWHAI-based tiers to help other organizations develop an advanced storage gas water heater initiative for North America.
- Encouraged manufacturer development of natural gas storage water heaters that meet SEGWHAI performance tiers.
- Recommended future work and initiatives regarding residential storage natural gas water heaters.

In addition, SEGWHAI communicated to a North American audience the importance of California's commitment to energy efficiency, as shown by the following:

- Funding provided by California Public Utilities Commission (CPUC) to California utilities for implementing natural gas energy efficiency programs for products such as SEGWHAI through 2014.
- Implementation of water heater incentive programs by California gas companies that will be expanded to include SEGWHAI-qualified units.

Conclusions

SEGWHAI findings indicate that adoption of performance-based technical specifications, such as SEGWHAI Tier 1 and Tier 2 standards, have the potential to fill an existing market gap and introduce significantly more efficient gas storage hot water products. Using a public, open access approach, SEGWHAI created a network of stakeholders, supported by technical documentation and analysis, which now has the resources and motivation to develop and introduce SEGWHAI-based products. Implementation of SEGWHAI efficiency tiers is feasible and has the potential to significantly reduce natural gas consumption and CO_2 and NO_X emissions throughout North America. Additional funding for incentive programs and implementation of a prototype development phase will increase the natural gas and emissions savings potential.

Recommendations

Adopt SEGWHAI-tiered energy efficiency performance criteria and an ultra-low NO_X emission standard for water heaters throughout North America.

Support the use of SEGWHAI performance tiers by other organizations in developing an advanced residential gas storage water heater initiative.

Apply SEGWHAI tiers in establishing new ENERGY STAR** specifications for storage gas water heaters.

Benefits to California

California will benefit from the implementation of a SEGWHAI-based water heater efficiency program in the following ways:

- Reduce water heating costs for California homeowners.
- Contribute to the State of California goal of reduced CO_2 emissions.

- Improve air quality through reduced NO_X emissions.
- Save millions of therms in support of the energy efficiency goals of Pacific Gas and Electric Company, Southern California Gas Company, and San Diego Gas & Electric Company.
- Strengthen reputation as the nation's leader in energy efficiency.

Over its lifetime, a SEGWHAI-compliant water heater has the potential to save between 400–700 therms, reduce CO_2 emissions by 2.4–4.1 metric tons, and avoid up to 13 pounds of NO_X emissions. If 50 percent of existing water heaters in the state were replaced with SEGWHAI Tier 1 units, California households would save more than $154 million each year in natural gas costs, and California would avoid annual emissions of more than 900,000 metric tons of CO_2 and nearly 5 million pounds of NO_X. The CPUC values these emission reductions at more than $30 million/year (E3 2006b).

Chapter 1: Introduction

1.1. Background and Overview

Gas water heating accounts for more than 40% of residential natural gas use in California. More than 10 million California households use standard small gas storage water heaters with an average energy factor (EF) of 0.58. Together, the water heaters in these households generate significant emissions of carbon dioxide (CO_2) and oxides of nitrogen (NO_X). High efficiency water heaters, including tankless and high-capacity condensing units,[1] are cost-prohibitive to install in most replacement and new construction applications. The Super Efficient Gas Water Heating Appliance Initiative (SEGWHAI) was conceived to fill the gap between standard and high efficiency products in the residential natural gas storage water heaters marketplace, as is illustrated in Figure 1-1. SEGWHAI aimed to generate the necessary market pull and foster partnerships to develop cost-effective storage water heaters that produce 30% energy savings and a 50% reduction in NO_X emissions over currently available standard efficiency units.

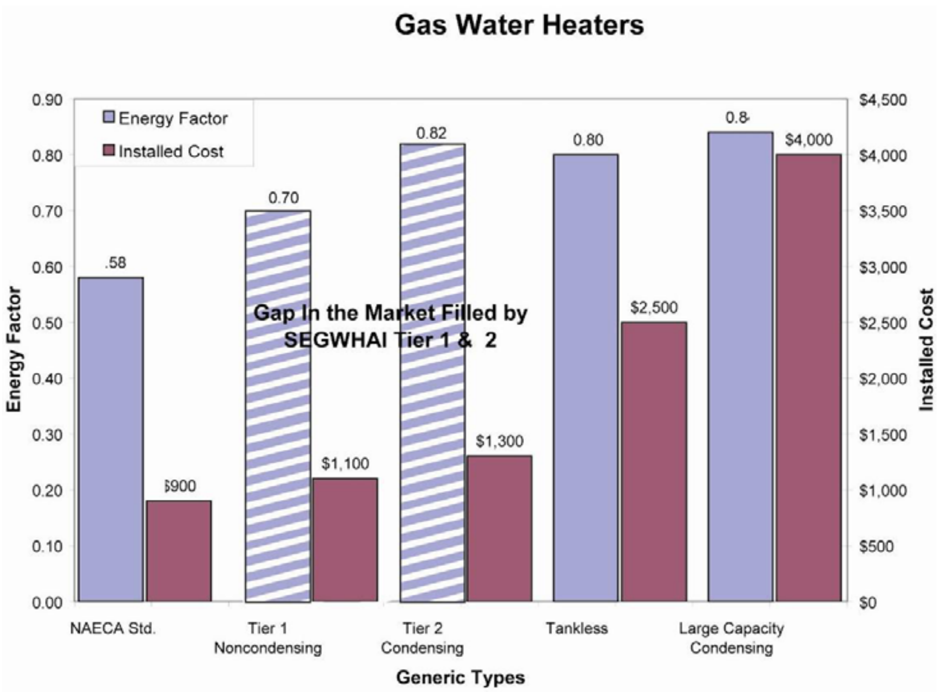

Figure 1-1. Market gap filled with proposed SEGWHAI based products

[1]. In the combustion process, non-condensing water heaters produce flue gas that is hot enough to exhaust atmospherically without producing condensate. These units typically do not achieve efficiency levels greater than EF 0.65. Condensing water heaters are characterized by the presence of high efficiency burners that combust and exchange heat more efficiently than non-condensing units, reaching efficiency levels greater than EF 0.80. These units produce lower temperature flue gas that condenses and does not rise through the flue. SEGWHAI Tier 1 criteria is for non-condensing units with EF of 0.70 and higher while Tier 2 criteria is for condensing units with EF ≥0.82 and higher.

Standard natural gas storage water heaters are installed in an estimated 58.2 million households throughout North America. If all units were replaced with products that meet SEGWHAI-based Tier 1 criteria, annual savings of up to 1793 million therms, 10.5 million metric tons (M/T) of CO_2, and 56.5 million pounds of NO_X are possible. The savings potential of SEGWHAI-compliant water heaters is therefore significant and cost-effective.

The conventional storage water heater market is essentially saturated and thus intensely competitive. To remain viable, manufacturers have focused their research and development (R&D) efforts on cost reduction and compliance with regulatory requirements, including flammable vapor ignition resistant (FVIR) designs and non-ozone depleting insulation-blowing agents. Few efforts have focused on developing innovative designs that increase energy efficiency and lower emissions.

The vision of SEGWHAI was inspired by the success of the Super Efficient Refrigerator Project (SERP) and European technology procurement programs. Rather than wait for a manufacturer to introduce a promising technology, technology procurement agencies work with stakeholders to establish the need, specifications, and market potential for products. External to SEGWHAI are the processes of the United States Department of Energy (U.S. DOE) Appliance Standards, the ENERGY STAR* program, the California Energy Commission's (Energy Commission) Title 20 and Title 24 standards, and the South Coast Air Quality Management District (SCAQMD), all of which impact the introduction of products that fill the market gap.

1.2. Purpose

The purpose of the SEGWHAI scoping phase is to recommend technical specifications, stakeholder activities, and an implementation plan for the future of SEGWHAI. The project's conclusions and recommendations are based on detailed assessments of the current state of the California water heater market and the potential impacts of SEGWHAI. Input from program stakeholders throughout North America contributed significantly to the findings.

1.3. Project Objectives

The general objective of SEGWHAI was to implement a performance-based, comprehensive program to cost-effectively maximize energy efficiency and savings in the North American residential new and replacement water heater market. Specifically, SEGWHAI objectives were as follows:

- Establish a steering committee of project stakeholders to help develop criteria for super efficient residential storage gas water heaters for replacement and new construction applications.
- Conduct a series of steering committee meetings to establish consensus and build understanding amongst stakeholders. Support steering committee activities through project-developed research, outreach materials, and a communications website.
- Develop criteria for super efficient water heating appliances.
- Produce a final report that establishes the rationale and foundation for the proposed criteria.

- Recommend future work and initiatives regarding residential storage natural gas hot water heaters.

The steering committee, composed of stakeholders representing water heater manufacturers, utility partners, and industry organizations, was critical to the success of the program. By sharing technical area expertise, knowledge of market applications, and linkages between public- and private-sector research, the steering committee guided and supported development of SEGWHAI criteria and program design. The project team conducted five steering committee meetings to discuss concepts, promote coordination, and establish consensus amongst stakeholders. At steering committee meetings, stakeholders provide specific suggestions and recommendations for needed adjustments, refinements, or enhancement of the initiative.

With input from stakeholders, the authors developed a set of performance-based criteria for super efficient, low emissions water heaters. Criteria are further discussed in Section 4.1 SEGWHAI Technical Specifications. The authors make suggestions for future implementation of a SEGWHAI prototype phase in Section 4.2 Prototype Competition Plan. Another initial objective of the SEGWHAI scoping phase was to develop a Request for Proposals (RFP) to solicit improved storage water heater designs for the prototype development phase. However, based on stakeholder input, the authors did not develop an RFP or describe and execute a linear, multi-phased prototype development process. The project objectives were modified to incorporate the development of a multiple-phase, multiple entry–point concept in place of the original linear phasing plan.

Chapter 2: Project Approach

SEGWHAI established a Steering committee to meet periodically and guide research direction, review deliverables, and provide recommendations regarding information dissemination, market pathways, and commercialization strategies relevant to the research products.

In support of the research process, the authors conducted three surveys. First, they conducted a telephone survey of plumbers in Sacramento, Bakersfield, and Los Angeles to assess the consumer cost of replacement water heaters. The survey was based on business advertisements listed in city telephone books.

A second survey of installed water heaters was conducted by a home energy rater contractor. The contractor gathered data from more than 180 homes throughout California to determine, among other characteristics, water heater installation location, proximity to electrical and gas outlets, and gas line diameter. The information gathered allowed the authors to make general assumptions about typical installation sites and average burner capacity, as well as to prescribe specifications. SEGWHAI elected to not prescribe physical dimension characteristics, as so many water heaters are in garages where size is not critical. Also shown was that ½" gas lines that limit burner capacity are normal. Although maximum burner capacity is not specified, the survey shows that the potential low-cost installations will need to be 40,000 British thermal units per hour (Btuh) or less. To fully characterize the state of installed residential water heaters, a major study is needed that uses stratified sampling to generate statistically valid results.

Finally, a survey of water heater manufacturers was conducted. The survey was useful even if respondents didn't answer many of the questions because of valid proprietary concerns. Survey authors hope that these surveys served to increase manufacturer awareness of the issues other stakeholders—particularly utilities—face in implementing energy efficiency incentive programs.

To evaluate the potential costs and benefits of SEGWHAI water heaters, the authors used several analytic tools. Lawrence Berkeley National Laboratory's (LBNL's) Water Heater Analysis Model (WHAM) was used to estimate the anticipated energy use of SEGWHAI water heaters. A spreadsheet calculator developed by Energy and Environmental Economics (E3) for the California Public Utilities Commission (CPUC) was used to determine the maximum water heater incremental costs that would allow a SEGWHAI-based incentive program to be cost-effective.

The authors complemented the surveys and analyses with an extensive review of existing studies and data sources on topics including water heating technologies, U.S. and California energy and appliance statistics, gas efficiency programs, and air quality and climate change regulations. The results of this research and analysis, as well as SEGWHAI team expertise and Steering committee input and advice, were used in the preparation of the final report.

Chapter 3: Project Results

3.1 Energy and Environmental Benefits

3.1.1 Overview

Gas water heaters emit CO_2 and NO_X, thereby contributing to global climate change and exacerbating poor air quality. By improving water heater efficiency, SEGWHAI will lead to the reduction of CO_2 emissions. SEGWHAI water heaters must also comply with SCAQMD's Rule 1121, which requires a NO_X emissions reduction to below 10 nanograms/joule (ng/J). SEGWHAI is expected to result in per-unit CO_2 emission reductions of 17–33% and per-unit NO_X emission reductions of about 75% based on 40 ng/J standards.[2]

A spreadsheet calculator developed by E3 in 2006 was used to determine the maximum incremental consumer prices of SEGWHAI water heaters that would result in a cost-effective energy efficiency program. Maximum acceptable incremental costs range from $235 for a high efficiency non-condensing unit with a 13-year lifetime in Southern California Gas Company (SoCalGas) and San Diego Gas & Electric Company (SDG&E) service areas to $650 for a high efficiency condensing unit with a 20-year lifetime in a Pacific Gas & Electric Company (PG&E) service area. Program levelized costs (cost per therm saved) associated with these incremental costs range from $0.80–$1.00/therm. Analysts evaluated a number of program scenarios involving these incremental unit costs, a $100 million program budget, and different incentive structures. Depending on the type of incentive and the distribution of unit types by efficiency, a $100 million incentive program can involve anywhere from 150,000 to nearly a million water heaters. For more detail, see Section 3.1.5 E3 Results.

SEGWHAI's energy savings potential can be broken down into technical potential (savings if SEGWHAI units are installed at all technically feasible sites), economic potential (savings if units are installed everywhere they are cost-effective), and market potential (achievable savings assuming product incentives from public goods efficiency programs). SEGWHAI's technical savings potential is between 300–600 million therms per year (/yr) for California and between 1.8–3.5 billion therms/yr for the United States as a whole (once maximum market penetration is achieved). Economic potential, which depends on unit incremental costs and the details of particular installation sites, is estimated to be in the range of 70–110 million therms/yr for California and 300–380 million therms/yr for the United States. Market potential for efficiency programs totaling $100 million in incentives is in the range of 20–30 million therms/yr. In achieving these significant savings, SEGWHAI may reduce demand for natural gas enough to reduce both the natural gas market price and its price volatility (Wiser et al. 2005).

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[2]. As discussed in Section 3.1.2 Background, Oxides of Nitrogen, see pages 16 & 17. Background, and Section 3.1.5 E3 Results, these SEGWHAI NO_X emission reduction figures are uncertain due to lack of data on pilot light NO_X emissions.

3.1.2 Background

Carbon Dioxide

The combustion of fossil fuels releases CO_2, which is a major contributor to global climate change. Reducing the use of natural gas and other fossil fuels is imperative to avoid increasingly destructive climate impacts. In California, average temperatures are expected to rise by between 1.7–5.5°C (3–10°F) by the end of the century, depending on the CO_2 emissions rate. Experts contend an increased frequency of extreme climatic conditions will occur, including heat waves and droughts. Effects on the state are likely to include declining air quality, a sharp reduction in the size of the Sierra Nevada snow pack (a major source of the state's water), a disruption of agriculture and natural ecosystems, and a sea level rise (California Climate Change Center 2006). The more Californians are able to reduce CO_2 emissions, the less harmful these impacts are likely to be. Since California's example is often followed by other states, California's climate change policies are likely to have a powerful national and international impact.

To address the threat of climate change, Governor Schwarzenegger signed Executive Order S-3-05 in June 2005, which calls for California greenhouse gas (GHG) emissions to be reduced to 2000 levels by 2010; to 1990 levels by 2020; and to 80% below 1990 levels by 2050. The California Global Warming Solutions Act (AB 32), signed by the governor in September 2006, directs the California Air Resources Board to adopt regulations requiring GHG emissions to be reduced to 1990 levels by 2020. This will result in an estimated 25% reduction in emissions. Many methods are available to reduce GHG, including the following:

- Increased use of renewable electricity and transportation fuels, energy efficiency, conservation, and nuclear fission
- Carbon capture and storage
- Reduced deforestation

In their 2004 *Science* paper "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," S. Pacala and R. Socolow contend that "improvements in energy efficiency and conservation probably offer the greatest potential" to reduce GHG emissions. In particular, efficiency improvements in "space heating and cooling, water heating, lighting and refrigeration in residential and commercial buildings" could reduce worldwide 2050 carbon emissions from buildings and appliances by 25% compared to the business-as-usual scenario.

Water heating contributes 31% of the total residential CO_2 emissions in California, including emissions from electricity generation and natural gas (Figure 3-1).[3] Gas-fired water heaters

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[3]. The data presented in Figure 3-1, Figure 3-2, and Figure 3-3 were calculated using, in part, the Residential Appliance Saturation Survey (RASS) data on state electricity and natural gas use per household (Energy Commission 2004). The carbon intensities of natural gas and propane were obtained from the Energy Information Administration. The carbon intensity of California's electricity generation was calculated using U.S. DOE data on state-specific electric power emissions in 2002 (U.S. DOE 2006), and corresponding Energy Commission data on 2002 electricity generation (Energy Commission 2002). From these data, the authors calculated a carbon intensity of 0.33 lbs CO_2/kWh for the 2002 California electric power sector. In Figure 3-1, the CO_2 emissions resulting from hot water used for laundry and dishwashing are included in the "water heating" category, not the "laundry" and "dishwashing/cooking"

account for 90% of residential water heating emissions (Figure 3-2),[4] which is equivalent to about 28% of total residential emissions (31% x 90% = 28%).

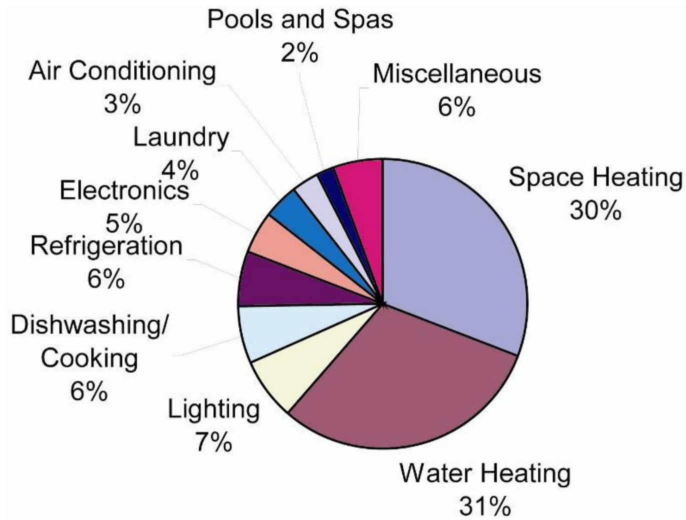

Figure 3-1. California residential CO_2 emissions by end-use, including both electricity and natural gas

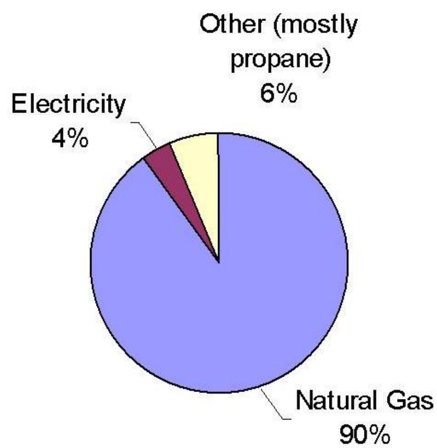

Figure 3-2. California residential water heating CO_2 emissions by fuel type

Water heating accounts for 44% of residential CO_2 emissions from natural gas in California (Figure 3-3).

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categories. Figure 3-1 does not include residential petroleum emissions, since RASS does not include a breakdown of petroleum end uses. However, other than outdoor barbecues [and transportation], petroleum supplies no more than 5% California households for any end-use category, and well under 5% in most categories (Energy Commission 2004a).

[4]. Figure 3-2 is based on RASS data for single-family water heating fuel shares. For dwellings with no individual water heating, RASS does not report water heating fuel.

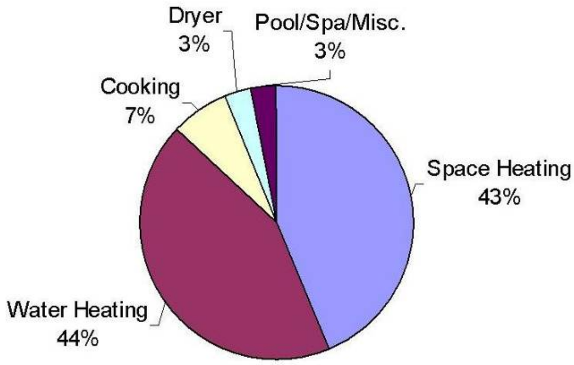

Figure 3-3. California residential CO_2 emissions from natural gas by end-use

All together, residential gas water heaters in California emit about 12 million M/T of CO_2/yr.[5] By increasing the efficiency of gas water heaters, SEGHWAI will reduce natural gas use and the associated CO_2 emissions. This will be an important component of the effort to reduce statewide GHG emissions and comply with climate change policies such as Executive Order S-3-05 and AB 32. Section 3.1.5 E3 Results provides estimates of SEGWHAI's CO_2 emission reduction impact.

Oxides of Nitrogen

In addition to generating CO_2, the combustion of fossil fuels at approximately 530°C (986°F) also releases significant amounts of NO_X, one of the six criteria pollutants regulated by the United States Environmental Protection Agency (U.S. EPA). NO_X is formed at high temperatures through the reaction of gaseous nitrogen (N_2) and oxygen (O_2), the major components of ambient air. NO_X contributes to ground-level ozone—an important precursor to smog—and acid rain, and causes a range of respiratory problems in humans. More than 55% of the U.S. population lives in ozone nonattainment areas (Figure 3-4)—or, areas where ozone levels exceed the National Ambient Air Quality Standard (NAAQS). States are required by federal law to take measures to improve air quality in nonattainment areas. A key way to address ozone pollution is to reduce NO_X emissions.

Gas water heaters are a significant source of NO_X emissions. In fact, each conventional storage gas water heater emits 12.25 lbs/yr of NO_X, which is as much NO_X/yr as driving 4000 miles in an average car (U.S. DOE 2005b). Water heater NO_X emissions can be reduced in the following two ways:

- Increasing water heater efficiency and thus reducing fuel use
- Modifying the water heater burner or pilot to reduce NO_X emissions directly

[5]. This value is based on the assumption that there are 10 million gas water heaters in California, that the average gas water heater energy consumption is 200 therms/yr, and that CO_2 is emitted at a rate of 0.00261 M/T/therm. The latter value is from the E3 calculator (discussed further below), and the former two values are discussed in Section 3.2 California's Small Gas Storage Water Heater Market.

The two most prevalent technologies for reducing NO_X emissions from gas-fired burners are low NO_X burners and flue gas recirculation, both of which reduce NO_X emissions primarily by cooling the temperature of combustion (EPA 1998).

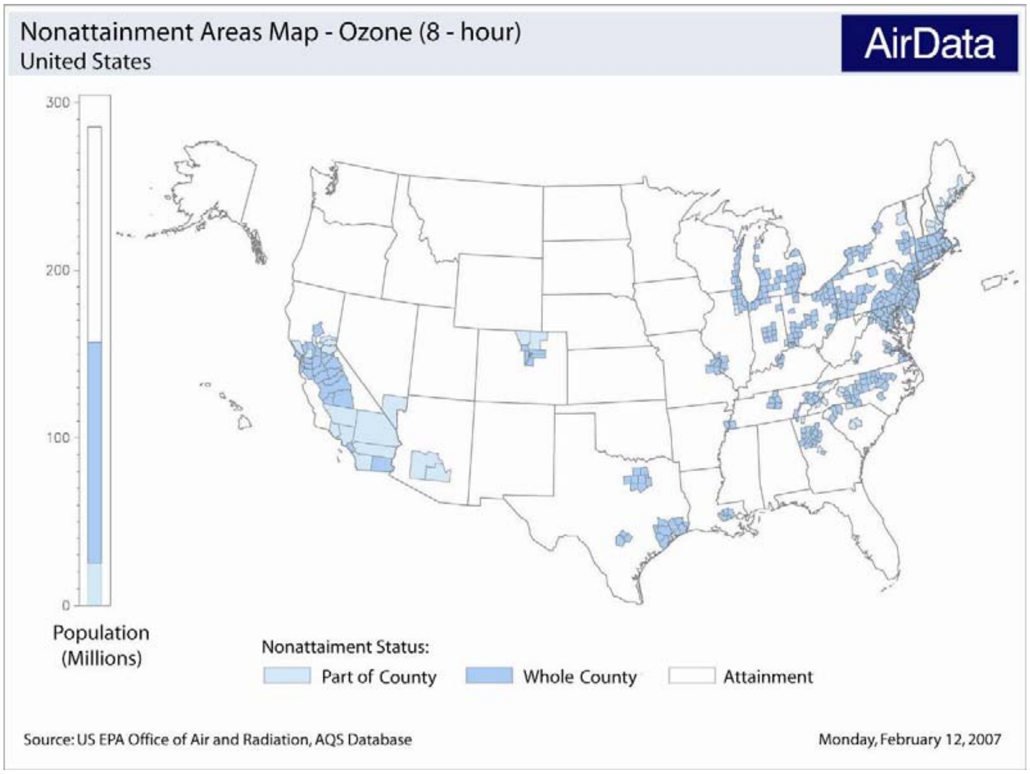

Figure 3-4. Map of U.S. ozone nonattainment areas (U.S. EPA 2006)

Among ozone nonattainment areas, Southern California is notable for its efforts to address NO_X emissions. The South Coast air basin exceeded federal ozone standards for 84 days in 2005, and maximum observed ozone levels were nearly twice as high as the NAAQS (SCAQMD 2006a). SCAQMD, the agency responsible for controlling air pollution in the region, regulates many sources of pollution, including residential water heaters. SCAQMD Rule 1121, adopted in 1978 and most recently amended in 2004, limits NO_X emissions from residential water heaters. Rule 1121 requires that water heaters with capacities ≤50 gallons (most residential units) sold in the district after January 1, 2006 emit NO_X at a rate no higher than 10 ng/J of heat output (0.00175 lb per therm of natural gas at a recovery efficiency (RE) of approximately 80%). However, in December 2005, water heater manufacturers were granted an 18-month variance and are now required to meet the 10 ng/J limit by July 2007. In addition, a six-month "sell-through" period was established from July–December 2007, during which water heater distributors, wholesalers, and retailers in the district will be permitted to sell noncompliant units that remain in stock. Water heater manufacturers are also required to pay a mitigation fee of $15 per unit for each noncompliant unit sold in the district after January 1, 2006, to fund NO_X reduction offset programs.

Manufacturers requested an additional three month extension in October 2006, from July to October 2007. Of the three major manufacturers, two reported that they will not be ready to bring 10 ng/J units to market until October 2007. The third manufacturer will be able to produce some 10 ng/J units beginning in July 2007, but will not be able to supply its full market share with these units until October. The three manufacturers also proposed reducing the sell-through period from six months to three months so that the final compliance date—by which all ≤50-gallon water heaters sold in SCAQMD must emit no more than 10 ng/J—remains January 1, 2008.

Many other California air districts followed the lead of SCAQMD when it adopted the 40 ng/J NO_X standard (which preceded the 10 ng/J standard), as shown in Table 3-1.

Table 3-1. California districts with NO_X emission limits of 40 ng/J for residential water heaters

Air Quality Management District (AQMD)	Regulation
San Joaquin Valley Unified Air Pollution Control District	Rule 4902
Bay Area **AQMD**	Rule 9-6
Sacramento Metropolitan **AQMD**	Rule 414
San Diego County Air Pollution Control District	Rule 69.5
Ventura County Air Pollution Control District	Rule 74.11
Santa Barbara County Air Pollution Control District	Rule 352
San Luis Obispo County Air Pollution Control District	Rule 428
Yolo-Solano **AQMD**	Rule 2.37
Kern County Air Pollution Control District	Rule 424
Antelope Valley **AQMD**	Rule 1121
El Dorado County **AQMD**	Rule 239
Placer County Air Pollution Control District	Rule 246

These districts are likely to follow SCAQMD's lead in adopting 10 ng/J standards after undergoing a period of adoption and processing. Moreover, other ozone nonattainment areas in the country (Figure 3-4) are under pressure to reduce NO_X emissions and thus are also likely to adopt some version of Rule 1121. For example, the Ozone Transport Commission, a multi-state organization responsible for addressing the ozone problem in the Northeast and mid-Atlantic U.S., could recommend a version of Rule 1121 that would affect 12 states and the District of Columbia.

Water heater NO_X emissions come from the two sources shown below:

- The pilot light, which burns gas continuously
- The burner, which fires only a few hours a day as needed to heat water

Pilot NO_X emissions are not currently covered by Rule 1121 since the SCAQMD test protocol only measures emissions when the burner is firing, not during standby. According to U.S. DOE (2000), water heater pilot lights consume 450 Btuh, which comes to 21% of the 185 therms/yr consumed by water heaters meeting 2006 standards (see Section 3.1.4 E3 Inputs). Therefore, if the pilot light emits NO_X at the same rate as the burner, the pilot accounts for 21% of the total unit NO_X emissions.

However, the pilot NO_x emissions rate is unknown.[6] Since the pilot is a diffusion combustion flame, its NO_x emissions rate may well be higher than the burner emissions rate, especially for Rule 1121 compliant products. If so, the pilot accounts for a larger percentage of total water heater NO_x emissions. For example, consider a Rule 1121 compliant water heater with a burner that emits NO_X at 10 ng/J (0.00175 lbs/therm), and assume that the pilot emits NO_X at four times this rate (0.0071 lbs/therm). In this case, the pilot would be responsible for 52% of the total annual water heater NO_x emissions.

Though replacing a continuous pilot light with an electronic ignition reduces water heater NO_x emissions substantially, this reduction is not recognized by Rule 1121. However, SCAQMD might be willing to allow a greater burner NO_x emissions rate from pilotless water heaters as long as the total unit emissions do not exceed the emissions of a standard Rule 1121 product with a continuous pilot. In the previous example of a Rule 1121 product with a pilot that emits at a rate of 0.0071 lbs/therm, removing the pilot while keeping the annual NO_x emissions from the water heater constant would allow the burner to double its emissions rate (from 10 ng/J to 20 ng/J) without increasing annual emissions. On the other hand, if the pilot emits NO_x at the same rate as the low NO_x burner, removing the pilot would allow burner emissions to increase to approximately 12–14 ng/J.

SEGWHAI recommends that implementing agencies require Rule 1121 compliance everywhere that SEGWHAI-based programs operate. This proposed requirement anticipates the likelihood that regulations similar to Rule 1121 will spread across much of the country. Rule 1121 compliance may also reduce the cost of NO_x reduction technologies, due to economies of scale. Estimates of SEGWHAI's potential NO_x emission reduction impact are presented in Section 3.1.5 E3 Results. Consideration of total NO_x emissions may allow pilotless water heaters to have somewhat higher burner NO_x output.

California Energy Efficiency Policy Structure

California public policy focuses on becoming more energy efficient as the preferred method for utilities to consider when seeking to meet new electricity and natural gas demand. A therm or kilowatt hour of energy or a kilowatt of peak energy saved by utility customers benefits all customers because it is the lowest cost resource. While energy efficiency will not meet all of the increasing energy needs of a growing population, it reduces the societal cost of providing for increased energy demand.

The CPUC has decoupled Investor-Owned Utility (IOU) income from the sales volume of natural gas and electricity. As such, energy efficiency programs do not reduce IOU income and profitability. California IOUs, including PG&E, SoCalGas, and SDG&E, regularly collect public purpose program funds from ratepayers to support energy efficiency programs, as deemed by the CPUC. The CPUC is establishing incentive mechanisms that reward IOUs for achieving and exceeding energy efficiency goals. On a three-year cycle, IOUs propose a portfolio of energy efficiency programs they will administer to achieve applicable CPUC adopted efficiency goals. With approval of the CPUC, IOUs implement and administer approved portfolio of energy efficiency programs.

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[6]. PG&E plans to collect gas pilot light NO_x emissions data soon.

Gas Savings and Efficiency Goals

Policies to reduce CO_2 and NO_X emissions encourage the development of more efficient gas water heaters. In addition, the CPUC, which regulates California's investor-owned gas utilities (PG&E, SoCalGas, and SDG&E), has adopted aggressive natural gas savings goals (Decision 04-09-060). Decision 04-09-060 calls upon utilities to double annual gas savings between 2004 and 2008 (from 21 million therms to 44 million therms), and to more than triple gas savings (to 67 million therms) by 2013 (CPUC 2004). Gas utility efficiency program administrators are therefore under pressure to adopt gas efficiency programs that will help them meet these goals. The California utilities have not resisted these policies, in part because their profits are decoupled from the volume of gas they sell (see Section 3.4 Roadmap for Commercialization, Outreach, and Marketing).

3.1.3 E3 Background

The consulting firm E3 has developed a spreadsheet calculator that is used by the CPUC to determine the cost-effectiveness of energy efficiency programs. E3 has released separate versions of the spreadsheet for each of the major California utilities as energy costs and cost projections vary by region. These spreadsheets are publicly available (E3 2006a), and can be used to evaluate incentive programs for energy efficient products. Given the incremental cost of the efficient product, the product lifetime, its energy (natural gas and/or electricity) savings, the incentive (rebate) available per unit, and the number of units installed per quarter, the calculator returns the program budget, total energy savings, levelized cost (in dollars per unit of energy saved), the benefit-cost ratio (BCR), and emission reductions (CO_2, NO_X, and, for electricity, PM-10). The levelized costs and BCRs discussed in this report are total resource cost (TRC) values, meaning that they take into account costs incurred both by program participants (out-of-pocket cost for the efficient product) and by the utility (rebates and administrative costs). TRC values are independent of rebate amounts as TRC is the same whether the incremental costs of efficient products are paid by consumers or by society through utility rebates.

The E3 calculators were used to evaluate four possible types of SEGWHAI water heaters and the current rebate-eligible product, (EF 0.62). Product EF and lifetimes are presented in Table 3-2. The high efficiency non-condensing product (EF 0.70) is the minimum-efficiency SEGWHAI Tier 1 product, and the medium efficiency condensing product (EF 0.82) represents the minimum-efficiency SEGWHAI Tier 2 product. See Section 4.1 SEGWHAI Technical Specifications for more information about the SEGWHAI tiers.

3.1.4 E3 Inputs

Useful Life

As presented in Table 3-2, most SEGWHAI products were assumed to have a useful life of 13 years. This is the effective useful life estimate given in the Database for Energy Efficiency Resources (see Section 3.2 California's Small Gas Storage Water Heater Market). One hypothetical high efficiency condensing product with a 20-year lifetime was also considered.[7]

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[7]. If such "long life" products were included in SEGWHAI, manufacturers would presumably be required to vouch for the product lifetimes by offering 20-year warranties. Manufacturers may be reluctant to offer such long warranties for products that have not been around long enough for their lifetimes to be well

Table 3-2. Summary of water heater types evaluated using E3

Product Type	EF	Lifetime in years
Current efficiency program product	0.62	13
High efficiency non-condensing product	0.70	13
Medium efficiency condensing product	0.82	13
High efficiency condensing product	0.86	13
High efficiency condensing product, long life	0.86	20

Energy Savings

Estimates of SEGWHAI energy savings were developed using the WHAM, which was developed at the LBNL. WHAM is a simple energy equation that calculates water heater energy consumption by taking into account seven parameters shown below:

- RE
- Standby heat loss coefficient
- Rated input power
- Average daily hot water draw volume
- Inlet water temperature
- Thermostat setting
- Air temperature around the water heater (Lutz et al. 1999)

Based on WHAM calculations, the SEGWHAI team approximates the energy use of new, baseline efficiency water heaters at 185 therms/yr. This is based on an assumed 65% distribution of 40-gallon units and 35% distribution of 50-gallon units, respectively.[8] The WHAM model is used to calculate energy use and savings for the product efficiency levels shown in Table 3-3.

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documented. California gas utilities give a $30/unit rebate for water heaters that have an EF of 0.62 or higher which is referred to in this report as "current efficiency program product".

[8]. This distribution is based on data presented by Robert Mowris & Associates (2004). Though these percentages actually apply to water heaters with EFs a few percentage points above the minimum (up to 0.64), this is likely to be a good estimate of the distribution of baseline EF units as well. A small survey of residential water heaters in California, conducted by Amaro Construction Services, found that approximately 57% of water heaters surveyed were 50-gallons or larger. Due to the relatively small sample size, the information was not used as a representational distribution data. For more information, see Section 3.2.5, California Water Heater Field Survey.

Table 3-3. Energy savings associated with efficient gas water heaters[9]

Product Type	EF		Annual Energy Consumption (therms/yr)	Annual Energy Savings (therms/yr)	Lifetime Energy Savings (therms)
	40 gal	50 gal			
Baseline	0.60	0.58	185	-	-
Current efficiency program product	0.62	0.62	176	8.9	116
High efficiency non-condensing product	0.70	0.70	154	30.8	401
Medium efficiency condensing product	0.82	0.82	131	54.1	703
High efficiency condensing product	0.86	0.86	124	60.2	783
High efficiency condensing product, long life	0.86	0.86	124	60.2	1205

Some SEGWHAI units are likely to require a small amount of electricity for electric ignition and potentially additional electricity for a combustion air blower. In that case, the energy savings input into the E3 calculators would need to take into account the increased electricity use as well as the decreased gas use in the absence of a pilot. Any electricity used by SEGWHAI units will be small compared to their gas savings; however, the authors have neglected changes in electricity use in order to simplify the preliminary analysis.[10] For additional clarity and simplicity, SEGWHAI tiers are the same for all capacities as this practice is used in existing water heater rebate programs.

Number of Units

Each product type was evaluated with the E3 model. Each model run assumed an installation rate of 20,000 units per quarter, or a total of 400,000 units over an assumed five year program period. In the program scenarios evaluated, different combinations of the four types of products were considered, with the total number of units dependent on the program budget. Therefore, the scenarios included a range of different numbers of units (see Section 3.1.5 E3 Results).

[9]. Annual energy consumption, annual energy savings, and lifetime energy savings are weighted figures based on an assumed distribution of 65% 40-gallon units and 35% 50-gallon units.

[10]. A Davis Energy Group study for PG&E (Davis Energy Group 2007) found that the average electrical use for tankless water heaters (with electric components similar to expected SEGWHAI qualifying products) is 57 kWh/yr. Depending on the fuel costs, the cost of this electricity would 10-20% of the value of the gas savings of SEGWHAI products.

Program Administrative Cost

Administrative costs were estimated at $2 million for the assumed $100 million program. Given a rough program size estimate of 400,000 units, this comes out to $5 per unit. This is a reasonable administrative cost target for a highly effective program. Alternative scenarios can be run by those wishing to explore the impact of various changes to input values.

Program Incentives

As mentioned above, the financial incentive (rebate) offered per unit does not affect the BCR or the levelized cost of the program as these are TRC values. Therefore, the authors did not use E3 to evaluate different incentive levels. Rather, the maximum calculated incremental costs were used to evaluate different program scenarios involving different incentives and unit numbers (Section 3.1.5 E3 Results). Incentives can be directed at consumers, manufacturers, wholesalers, and retailers (Section 3.4 Roadmap for Commercialization, Outreach and Marketing).

Incremental Cost

This report follows the E3 calculator in using the term "incremental cost" to refer to incremental consumer price, not manufacturing cost. The incremental cost of the efficient product, the difference between its cost and the cost of the conventional product, is treated in the E3 calculator as an input. However, for this analysis, incremental cost was treated as an output through a series of iterations. The calculator was used to determine the maximum possible incremental cost that would allow the program to generate a BCR ≥1 for each type of product. The results give water heater manufacturers an estimate of the maximum retail prices that could be charged for different efficiency levels to meet the SEGWHAI objectives.[11] These prices may not be achievable immediately; however, with increased production volume and experience, costs will fall until a mature market price is reached. It is this mature market price that must be below the maximum calculated here. If actual incremental prices are lower than the maximum, E3 calculated BCRs will be greater than 1. Incremental cost calculations depend upon E3 assumptions regarding the cost per therm of gas saved. E3 assumes that this decremental gas rate is $1.21/therm for 2006, and increases at a rate of 2%/yr. If gas prices increase more rapidly than E3 predicts, higher incremental costs will be cost-effective.

3.1.5 E3 Results

Costs

As discussed above, the E3 calculator was used to find the maximum incremental installed cost of each type of efficient unit that would result in a TRC BCR of at least 1. Results for the three California gas utilities are presented in Table 3-4.

[11]. Manufacturers do not set retail prices for their products; manufacturing cost is only one of a number of factors that go into determining retail water heater prices.

Table 3-4. Maximum incremental cost as a function of product type and utility

Product Type	EF	Max. Incremental Cost ($/unit) for BCR = 1		
		PG&E	SoCalGas	SDG&E
Current efficiency	0.62	$67	$64	$64
High efficiency non-condensing	0.70	$247	$235	$235
Medium efficiency condensing	0.82	$438	$417	$418
High efficiency condensing	0.86	$488	$465	$466
High efficiency condensing, long life	0.86	$652	$546	$547

Maximum incremental costs are higher for PG&E than for SoCalGas and SDG&E because the projected price of gas (and so the value of gas savings) is higher in PG&E's service area. It is not surprising that maximum incremental costs are almost identical for SoCalGas and SDG&E, since both are owned by Sempra Energy and face very similar gas prices.

Table 3-5 presents the levelized cost of each type of efficient water heater, given the incremental costs listed in Table 3-4. All results are based upon the assumption of 400,000 units installed over five years in California.

Table 3-5. Levelized cost as a function of unit type and utility

Product Type	EF	Levelized Cost ($/therm) for BCR = 1		
		PG&E	SoCalGas	SDG&E
Current efficiency	0.62	$0.93	$0.90	$0.90
High efficiency non-condensing	0.70	$0.94	$0.89	$0.89
Medium efficiency condensing	0.82	$0.94	$0.89	$0.90
High efficiency condensing	0.86	$0.94	$0.89	$0.90
High efficiency condensing, long life	0.86	$1.00	$0.84	$0.84

PG&E has the highest levelized costs of the three utilities since the incremental product costs are slightly higher for PG&E (Table 3-4). It is not clear why the levelized cost increases for the long life product in the PG&E calculation, but decreases for the long life product in the calculations for the other two utilities. However, the authors believe that these results are not significant for the purpose of this report. In the results presented below, SoCalGas and SDG&E will be combined since they are similar.

Emissions

CO_2 emission reductions are a function of the reduction in natural gas use associated with improved efficiency. Using the E3 value of 0.00585 tons of CO_2 emitted per therm of natural gas, emissions of the baseline unit are (185 therms/yr)*(0.00585 M/T/therm) = 1.08 tons/yr. Annual and lifetime CO_2 emission reductions for each product are presented in Table 3-6. SEGWHAI water heaters are projected to reduce CO_2 emissions by 17–33% compared to the baseline.

Table 3-6. Projected carbon dioxide emission reductions

Product Type	EF	Annual CO_2 reduction per unit (M/T)	Lifetime CO_2 reduction per unit (M/T)	Percentage CO_2 reduction from baseline
Baseline	0.59	-	-	-
Current efficiency	0.62	0.05	0.68	5%
High efficiency non-	0.70	0.18	2.35	17%

condensing				
Medium efficiency condensing	0.82	0.32	4.11	29%
High efficiency condensing	0.86	0.35	4.58	33%
High efficiency condensing, long life	0.86	0.35	7.05	33%

NO_X emission reductions are also proportional to natural gas savings. In addition, since SEGWHAI products will be required to comply with the SCAQMD's Rule 1121, their NO_X emissions will be further limited to 10 ng/J of heat output (or 0.00175 lbs/therm of gas input), compared to a baseline of 40 ng/J (or 0.0071 lbs/therm).[12] Baseline unit emissions are (185 therms/yr)*(0.0071 lbs/therm) = 1.31 lbs/yr. NO_X emission reductions are presented in Table 3-7. The fourth column presents emission reductions that would be achieved as a result of reductions in natural gas use if NO_X emissions per therm remained constant. The fifth, sixth and seventh columns also include emission reductions resulting from compliance with SCAQMD's revised Rule 1121 (for all but the baseline and current efficiency products). A baseline efficiency Rule 1121 compliant water heater reduces NO_X emissions by 71% compared to the baseline, while the SEGWHAI units reduce emissions by 74–78% compared to the baseline.

[12]. 40 ng/J is the current Rule 1121 requirement, applicable in the South Coast district until the 10 ng/J requirement comes into force (for residential units) in January 2008.

Table 3-7. Projected NO_X emission reductions

1	2	3	4	5	6	7
Product Type	**EF**	**NO_X emissions rate (ng/J)**	**Annual NO_X reduction per unit from gas savings only (lbs)**	**Annual NO_X reduction from gas savings AND Rule 1121 compliance (lbs)**	**Lifetime NO_X reduction from gas savings and Rule 1121 compliance (lbs)**	**Percentage NO_X reduction from baseline**
Baseline	0.59	40	-	-	-	-
Current efficiency	0.62	40	0.06	0.06	0.83	5%
Current efficiency, low NO_X	0.62	10	0.06	0.93	12.10	71%
High efficiency non-condensing	0.70	10	0.22	0.97	12.59	74%
Medium efficiency condensing	0.82	10	0.38	1.01	13.12	77%
High efficiency condensing	0.86	10	0.43	1.02	13.26	78%
High efficiency condensing, long life	0.86	10	0.43	1.02	20.41	78%

All of the high efficiency water heaters presented in Table 3-7 (≥EF 0.70) are assumed to have electronic ignition rather than continuous pilot lights. This complicates the analysis for two reasons. First (as discussed in Section 3.1.2 Background), Rule 1121 does not recognize pilot NO_X emissions, so the SCAQMD-recognized emissions reductions would be smaller than the actual reductions. Second, the calculations assume that the pilot emits NO_X at the same rate as the burner. In fact, the pilot may emit NO_X at a higher or lower rate. These calculations need to be adjusted when pilot NO_X emissions data become available. Once these data are available, SCAQMD may decide to allow pilotless water heaters to meet a relaxed burner NO_X emissions standard (see Section 3.1.2 Background).[13]

Program Scenarios

The results presented above are based upon modeling each product type individually. However, an actual incentive program is likely to involve a variety of incentive levels, or tiers, for different product types. Several sample program scenarios that utilities might implement are presented below. The purpose of this analysis is to investigate of the potential scope of utility incentive programs. Each scenario has a program budget of $100 million (including $2 million in administrative costs), but incentive structures and product mixes differ. The three different potential incentive structures presented in Table 3-8 are as follows:

[13]. Collaboration on this issue between SEGWHAI stakeholders and SCAQMD is recommended.

- Incentives of $10 per EF point above 0.60, with an additional $40 for the product with the 20-year life
- Incentives equal to the incremental cost of the product
- Incentives equal to half of the incremental cost of the product

Incentives based on incremental product costs differ between PG&E and the Southern California utilities as incremental costs differ in these regions due to different gas price projections. These incentives may be directed at consumers, manufacturers, wholesalers, and retailers (Section 3.4 Roadmap for Commercialization, Outreach and Marketing).

Table 3-8. Possible SEGWHAI incentive levels. IMC stands for incremental measure cost.

		Incentive Structures				
		All Utilities	PG&E		SoCalGas/SDG&E	
Product	EF	$10/EF Point	Equal to IMC	Half of IMC	Equal to IMC	Half of IMC
High efficiency non-condensing	0.70	$100	$247	$124	$235	$118
Medium efficiency condensing	0.82	$220	$438	$219	$417	$209
High efficiency condensing	0.86	$260	$488	$244	$465	$233
High efficiency condensing, long life	0.86	$300	$652	$326	$546	$273

Four different product distributions are considered in the program scenarios below:

- An equal number of each product type
- A distribution with the maximum number of units (all units are of the least costly type)
- A distribution with the minimum number of units (all units are of the most costly type)
- An estimated market-driven diversified distribution (67% of the EF 0.70 product, 23% of the EF 0.82 product, and 5% of each of the EF 0.86 units)

In Table 3-9, four $100 million program scenarios with the $10/EF point incentive structure are presented along with these four product distributions. In Table 3-10, program scenarios with incentive structures based on incremental costs are presented. Numbers of units presented are approximate, and are intended to provide a general sense of what such programs might entail.

Table 3-9. Sample program scenarios with incentives of $10/EF point (plus an additional $40 for the long-lived product)

Scenario	Incentive	Product Mix	Number of Units	Program EF	Millions of Therms Saved/yr by CA IOUs (after 5 years)
1	$10 per EF point	Equal distribution	444,000	0.81	22.8
2	$10 per EF point	Maximum # of units	980,000	0.70	30.2
3	$10 per EF point	Minimum # of units	327,000	0.86	19.7
4	$10 per EF point	Market-driven distribution	672,000	0.74	26.3

Table 3-10. Sample program scenarios with incentive levels based on product IMC as it varies by CA IOU

Scenario	Incentive	Product Mix	Number of Units: PG&E	Number of Units: SoCalGas /SDG&E	Pro-gram EF	Millions of Therms Saved/yr (after 5 years): PG&E	Millions of Therms Saved/yr (after 5 years): SoCalGas/ SDG&D
5	Equal to IMC	Equal distribution	214,000	236,000	0.81	11.0	12.1
6	Equal to IMC	Maximum # of units	395,000	415,000	0.70	12.2	12.8
7	Equal to IMC	Minimum # of units	150,000	180,000	0.86	9.0	10.8
8	Equal to IMC	Market-driven distribution	304,000	322,000	0.74	11.9	12.6
9	Half of IMC	Equal distribution	428,000	472,000	0.81	22.0	24.2
10	Half of IMC	Maximum # of units	790,000	830,000	0.70	24.4	25.6
11	Half of IMC	Minimum # of units	300,000	360,000	0.86	18.1	21.7
12	Half of IMC	Market-driven distribution	609,000	642,000	0.74	23.8	25.1

A number of interesting points can be drawn from these tables. Depending on program design, the number of water heaters included in a $100 million program can range from 150,000 to nearly one million. Maximizing the number of units requires including only the least-cost (high efficiency non-condensing) units. For each type of incentive, increasing the program EF while keeping the budget constant requires decreasing the total number of units. The market-driven distribution scenarios are probably the most realistic, and range from 300,000–670,000 units, depending on how the incentives are structured. However, it is important to note that the incremental costs used in Table 3-10 were calculated from E3 model scenarios in which 400,000 units of a single product type were installed over five years. When a few preferred program scenarios are selected, the program details should be revised by evaluating these scenarios individually using the E3 model.

3.1.6 SEGWHAI Potential Savings

Building on a long tradition in efficiency work, the California Energy Efficiency Potential Study (Itron et al. 2006) distinguishes three types of energy efficiency potential:

- Technical potential
- Economic potential
- Market potential

Technical potential refers to the energy savings that would be achieved if all efficiency improvements were installed wherever technically feasible. Economic potential refers to the energy savings that would be achieved if efficiency improvements were installed where they were technically feasible and cost-effective. Market potential refers to the expected energy savings from particular program scenarios.

Technical Potential

About 10 million households in California use gas water heaters (Section 3.2 California's Small Gas Storage Water Heater Market). If all of these units were replaced with high efficiency non-condensing SEGWHAI units, energy savings would reach more than 300 million therms/yr compared to the baseline new water heaters. If all water heaters were replaced with medium efficiency condensing SEGWHAI units, energy savings would exceed 500 million therms/yr. If all units were replaced with high efficiency condensing units, savings would exceed 600 million therms annually. These technical potentials, as well as corresponding potentials for the United States as a whole and for Canada, are presented in Table 3-11. U.S. figures are based the Residential Energy Consumption Survey (RECS), which reports that 58.2 million households in the nation use gas water heating (U.S. DOE 2001). Natural Resources Canada (NRCan) (2006) reports that there are 12.4 million households in that country (as of 2004), of which 44.6% (5.5 million) use gas water heating.

Table 3-31. SEGWHAI technical potential

	Technical Potential (millions of therms/yr)		
Region	**EF 0.70**	**EF 0.82**	**EF 0.86**
California	308	541	602
United States	1,795	3,149	3,506
Canada	170	298	331
Total U.S. and Canada	1,965	3,447	3,837

Economic Potential

The technical potentials presented above refer to the case in which all residential gas water heaters are replaced with SEGWHAI units. In fact, SEGWHAI units will not be cost-effective at all sites. SEGWHAI's economic potential depends on the costs of SEGWHAI units and the percentage of households at which SEGWHAI units can be installed without major renovation. Prior to the development of SEGWHAI products, it will not be possible to determine SEGHWAI's economic potential precisely. For the purpose of this analysis, the authors assume that SEGHWAI units will be cost-effective if the incremental installation costs are minimal.

The major difference between the installation of conventional gas storage water heaters and SEGWHAI high efficiency non-condensing units is that the latter is likely to require 110 volt (V) electrical service. If the installation of a SEGHWAI unit requires a new electrical outlet to be installed, the incremental installation cost will increase by $50–$100 (Reed Construction Data 2007). With this extra cost, SEGHWAI high efficiency non-condensing products may be less cost effective. However, since appliance cords are typically six feet (ft) long, the incremental installation cost of these units will be minimal at sites that already have a 110 V outlet within six ft of the water heater. A site survey of 181 California homes (presented in Section 3.2 California's Small Gas Storage Water Heater Market) found that 21% of surveyed water heaters were within six ft of a 110 V outlet. Though the survey is not representative of all California residences, these results can be used to make a preliminary estimate of the economic potential of high efficiency non-condensing water heaters. The problem of electrical power is mitigated if 24 V power is needed as it is easy to run wire from a transformer at a 110 V outlet. Taking a cautious approach, the SEGWHAI team estimates that the economic potential of SEGHWAI high efficiency non-condensing units is equal to 21% of the technical potential of these units (Table 3-12).

Installation requirements are more extensive for SEGWHAI condensing units than for non-condensing units. As well as requiring electricity, condensing units require a condensate disposal line that runs directly from the water heater to a drain or outside. The installation of such a line will be the least costly at sites in which the water heater is installed in the garage. Garage installation is therefore used here as a proxy for an easily accessible condensate drain. The California site survey found that 18% of water heaters were both (1) within six ft of a 110 V outlet, and (2) installed in a garage. However, water heaters are much more commonly installed in garages in California than in other parts of the country, where basement installation is common. A survey by the Gas Research Institute (GRI) (Crisafulli 1996) found that in Midwestern and Northeastern cities (Boston, Buffalo, Chicago, Cleveland, Milwaukee, and Minneapolis), the vast majority of water heaters are installed in basements, and less than 1% are installed in garages. On the other hand, in Western and Southern cities (Atlanta, Charlotte, Dallas, Los Angeles, Phoenix, Raleigh, Seattle), a significant fraction of water heaters are installed in garages. The authors therefore assume that the California site survey results could be extended to the Western and Southern United States, but not to the Midwest and Northeast census region homes as they typically have water heaters installed in the basement. Data on the number of homes with gas water heating in each of these four regions was obtained from RECS.

Table 3-12 presents SEGWHAI's economic potential, assuming that non-condensing SEGHWAI units are cost-effective at sites where the water heater is within six ft of a 110 V outlet, and that condensing water heaters are cost-effective at sites where the water heater is within six ft of a 110 V outlet and installed in the garage. SEGWHAI's Canadian economic potential is not presented because data on Canada's existing water heater installations is not available.

Table 3-42. SEGWHAI economic potential

	Economic Potential (millions of therms/yr)		
Region	**EF 0.70**	**EF 0.82**	**EF 0.86**
California	65	97	108
United States	377	297	331

Energy Efficiency Program Market Potential

Market potential is defined relative to a particular program scenario. Table 3-13 presents energy savings associated with the $100 million SEGWHAI program scenarios presented in Table 3-9 for California, which involve incentives of $10/EF point. As noted above, these incentives could be directed at consumers, manufacturers, wholesalers, retailers, and/or installers. Approximately 4.8 million residential gas water heaters are purchased each year in the United States (see 3-10). In these scenarios, SEGWHAI units would account for up to 4% of these purchases each year for five years. The total number of residential gas waters in the United States is estimated at 58.2 million (U.S. DOE 2001), with a total baseline energy consumption of 10.8 billion therms/yr. Projected market potential for a $100 million SEGWHAI program represents implementation of SEGWHAI units in 4% of households resulting in a reduction of up to 0.3% of annual U.S. gas water heater consumption.

Table 3-53. SEGWHAI market potential

Scenario	Incentive	Product Mix	Number of units in 5 years	Market Potential (millions of therms/yr after 5 years)
1	$10 per EF point	Equal distribution	444,000	23
2	$10 per EF point	Maximum # of units	980,000	30
3	$10 per EF point	Minimum # of units	327,000	20
4	$10 per EF point	Market-driven distribution	672,000	26

SEGWHAI market potential can also be assessed relative to the CPUC's natural gas savings goals. The CPUC has dedicated $368.2 million to gas energy efficiency programs in 2005–2008 and aims to reduce statewide natural gas use by about 252.7 million therms/yr by 2014 through efficiency programs, with funding totaling $1.3 billion (CPUC 2004). The California gas utilities are therefore under pressure to implement programs that reduce household gas use. Table 3-14 presents CPUC natural gas savings goals and funding, and illustrates one scenario in which SEGWHAI Tier 1 units contribute to meeting these goals. High efficiency residential water heaters could meet about 26% of the savings goal, with a market share that rises steadily to about 30% in 2014.

Table 3-64. CPUC statewide natural gas savings goals and potential SEGWHAI contributions

Year	Annual Natural Gas Savings Goals (MM therms/yr)	Program Funding ($ millions)	SEGWHAI Potential Contribution to Goals (MM therms/yr)	SEGWHAI Units Installed
2005	15.4	75.0	-	-
2006	17	83.8	-	-
2007	19.4	96.3	0.061	2,000
2008	22.5	113.1	0.304	10,000
2009	26.3	133.2	1.520	50,000
2010	27.2	139.2	3.040	100,000
2011	27.1	140.2	4.560	150,000
2012	30.4	159.2	6.080	200,000
2013	32.7	172.7	7.600	250,000
2014	35.3	188.0	9.120	300,000

Itron Study Estimates

The California Energy Efficiency Potential Study (Itron et al. 2006) provides estimates of the technical, economic, and market potentials of a number of different energy efficiency measures through 2016. Technical potential for all gas efficiency measures in existing residential buildings was estimated to be 972 million therms/yr by 2016, of which 420 million therms were attributed to gas water heating measures (including efficiency improvements in clothes washers, showerheads etc.), and about 30 million therms specifically to efficient gas water heaters. This latter figure is only 5–10% as high as this report's estimate of SEGWHAI's technical potential (300–600 million therms/yr for California; Table 3-11). The explanation for this discrepancy is that the Itron study considered only technologies that are currently on the market. In the case of efficient gas water heaters, only units with EF 0.63 were included. With a baseline of around 0.60, the savings associated with an improvement to 0.63 are far below the savings associated with the proposed SEGWHAI efficiencies of 0.70–0.86.

Itron estimated the economic potential of gas efficiency measures in existing residential buildings as 303 million therms/yr by 2016. For measures related to water heating, economic potential was estimated to be 225 million therms, but this estimate included just boiler controls, faucet aerators, low flow showerheads, and water heater wraps. Efficient water heaters themselves were not included in these estimates because the available products were not found to be cost-effective. Also, the Itron study used 2004 gas prices to calculate avoided costs and cost-effectiveness. Given the recent increase in gas prices, the Itron study almost certainly underestimated the economic potential of gas efficiency measures. In addition, Itron obtained water heater cost data from the Database for Energy Efficient Resources (DEER)[14]. As discussed in Section 3.2 California's Small Gas Storage Water Heater Market, the incremental cost provided by DEER for efficient (EF 0.63) water heaters is likely to be an overestimate.

[14]. Jointly developed by the CPUC and the Energy Commission to provide costs and energy savings for a range of energy efficient technologies and measures.

The concept of energy efficiency potential needs to be expanded to include emerging technologies such as SEGWHAI water heaters. Only considering technologies that are already on the market grossly underestimates the actual potential of energy efficiency measures.

3.1.7 Impact on Gas Price and Volatility

By reducing the demand for natural gas, efficiency programs such as SEGWHAI can contribute to the reduction of both the price of gas and price volatility. Economic theory supports the assertion that efficiency programs reduce the natural gas price, since they shift the demand curve for gas. In Figure 3-5, efficiency programs cause the gas demand curve to shift from "original demand" to "shifted demand", reducing the quantity demanded from Q_0 to Q_1 and reducing price from P_0 to P_1.

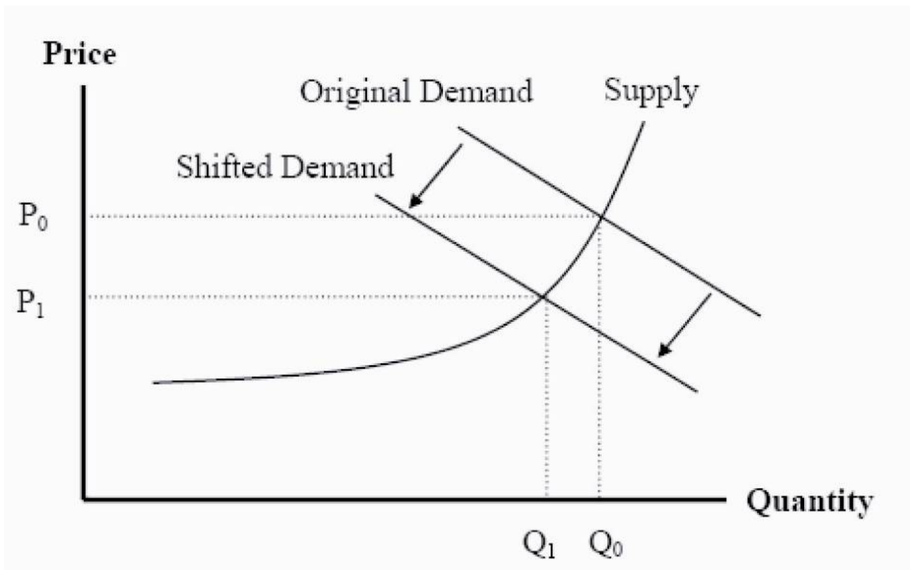

Figure 3-5. Efficiency impact on marginal price (Wiser et al. 2005)

In *Easing the Natural Gas Crisis*, LBNL researchers (Wiser et al. 2005) reviewed a number of studies and concluded that each 1% reduction in national gas demand will lead to a permanent reduction in wellhead gas prices of between 0.8–2%, which will be reflected in lower prices to consumers. These price reductions are likely to be even larger in the short term. A recent American Council for an Energy Efficient Economy (ACEEE) report, *Impacts of Energy Efficiency and Renewable Energy on Natural Gas Markets* (Elliot and Shipley 2005), found that efficiency programs that reduce both electricity and natural gas use by 4–5% nationwide would reduce the residential gas price by 10–20% through 2010. Regional programs can also have a significant impact: the ACEEE report found that a Midwest-only efficiency program could reduce the national wholesale gas price significantly, and reduce Midwest gas rates by 3–4% through 2010 (Elliot and Shipley 2005).

Reducing natural gas use through efficiency programs can also reduce the volatility of natural gas prices. An American Gas Foundation report, *Natural Gas and Energy Price Volatility* (Henning et al. 2003), found that the vast majority of volatility in gas prices in the early 2000s can be explained by two factors:

- Nearly all gas supply capacity was necessary to meet demand, leaving insufficient supply available to meet natural demand fluctuations
- Gas demand does not decrease significantly in response to short-term changes in gas prices

The report concludes that if we continue with business as usual, gas price volatility is likely to increase in the future. Figure 3-6 shows decreasing natural gas productive capacity in the continental United States as a result of the depletion of gas reserves. As productive capacity declines, actual production meets capacity increasingly often. This situation leads to increasing price volatility.

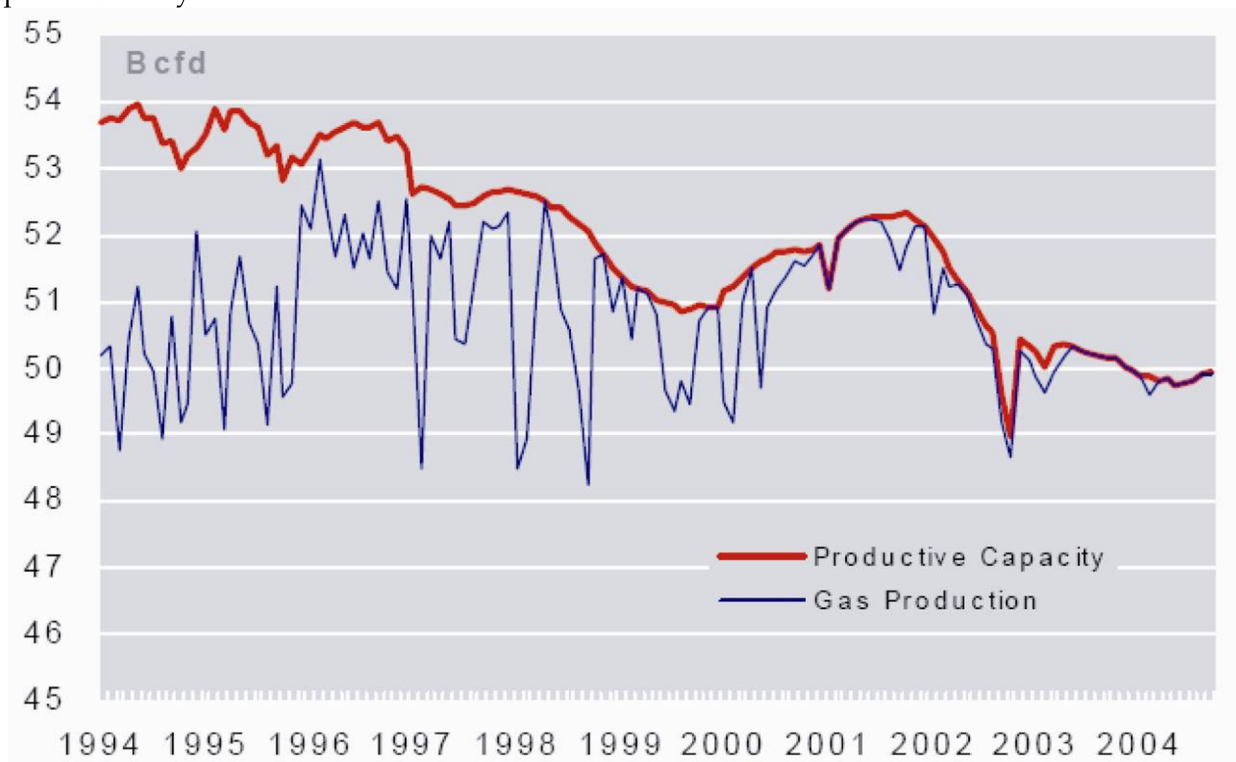

Figure 3-6. Dry gas production versus productive capacity in the U.S. lower 48 states from Kushler et al. 2005 (Energy and Environmental Analysis 2004)

Figure 3-7 is a simplified illustration of current market conditions. Demand naturally fluctuates between the levels labeled "Demand (low)" and "Demand (high)" due to changes in the weather. The supply curve is vertical beyond Q2, reflecting that this is a firm supply constraint (given existing pipeline capacity). When demand increases, the supply constraint is reached because the lower demand level is close to the supply constraint, causing price to increase dramatically (from P1 to P2). In other words, as demand fluctuates between the low and high levels, price fluctuates between P1 and P2.

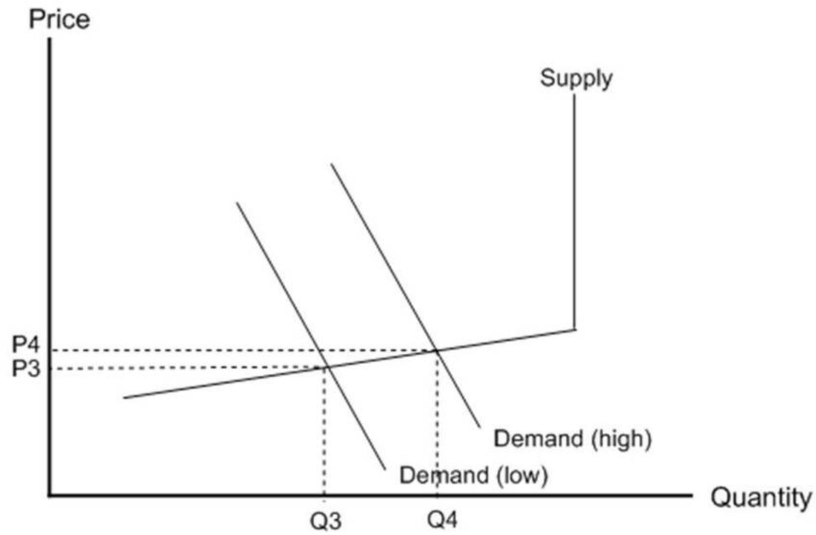

Figure 3-7. Impact of demand on price in a supply constrained environment

By reducing the demand for gas, efficiency programs such as SEGWHAI can contribute to the reduction of price volatility as illustrated in Figure 3-8. The supply curve is identical to the curve in Figure 3-7, but both demand curves have shifted due to the increase in gas efficiency. As a result, both low and high demand levels are below the supply constraint, so price fluctuates only between P3 and P4. Not only are overall prices lower than in Figure 3-7, but price volatility is severely reduced.

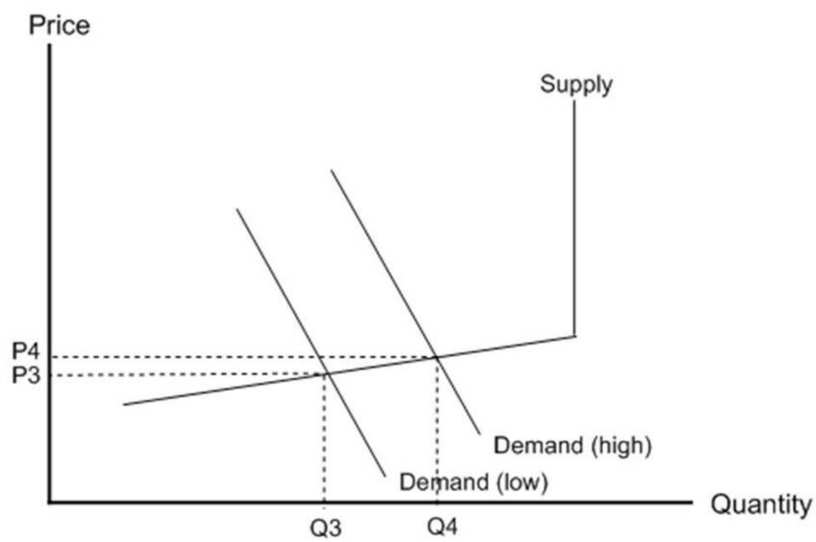

Figure 3-8. Impact of demand on price in a supply unconstrained environment

3.1.8 Recommendations for Future Action

In order for utilities to determine the baseline water heater efficiency against which improvements can be measured, they need access to data on the efficiency breakdown of water heater shipments to their states or regions. The Gas Appliance Manufacturer's Association (GAMA) should be able to assist utilities in obtaining this data from its members.

Other parts of the country will have different methods for calculating the costs and benefits of energy efficiency programs that introduce SEGWHAI qualified products to the market. Utilities and other market participants who are doing cost-benefit analyses should coordinate and cooperate to standardize program assumptions where possible.

More importantly, however, the results presented in this report suggest that incentives for high efficiency, low NO_X water heaters could be a cost-effective means of reducing natural gas usage, air pollution, and GHG emissions. Based on energy and environmental considerations, the team therefore strongly recommends the implementation of incentive programs throughout North America for SEGHWAI water heaters.

3.2 California's Small Gas Storage Water Heater Market

3.2.1 Overview

Of the 12 million households in California, around 10 million use gas water heaters. Gas water heating accounts for 44% of California residential natural gas use. Improvements in the efficiency of baseline gas storage water heaters over the past two decades have been relatively minor, and the average EF of gas water heaters installed in the state is currently about 0.58. However, with a replacement rate of close to a million units a year, the potential exists to rapidly improve gas water heating efficiency.

Three major manufacturers are responsible for 99% of the tank water heaters sold in the United States. These manufacturers sell water heaters to plumbing wholesalers who sell to plumbing contractors or directly to consumers or large ("big box") retailers. A survey of 52 water heater installers in three California cities found that the installed cost of a typical 40-gallon replacement unit is around $900.

A field survey of California water heater installations gathered information on installed water heater characteristics, including water heater location, storage volume, insulation, gas line size, and availability of a nearby electrical outlet. In most houses surveyed, the water heaters are naturally vented 40- to 50-gallon units installed on platforms in garages, connected to ½" gas lines that deliver gas to 40,000 Btuh burners. Characterization of existing water heater installations is valuable in determining the potential future market share for SEGWHAI qualified water heaters that may require electricity, condensate drains, and flue replacements.

3.2.2 Gas Water Heating Market Overview

Gas Water Heater Market Share

The 2003 Residential Appliance Saturation Study (RASS) collected data on the saturation of residential appliances as well as characteristics of the California residential population, dwellings, and energy use patterns (Energy Commission 2004). According to RASS, gas water heating accounts for a full 44% of residential natural gas use in California (Figure 3-9).

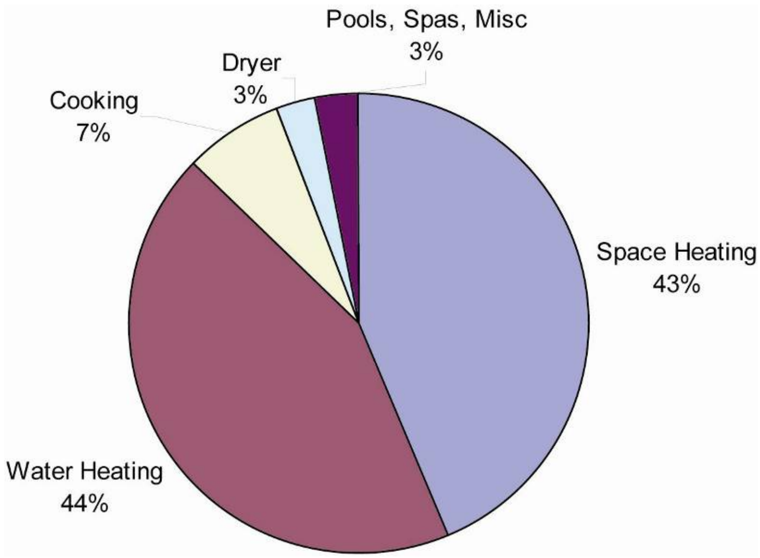

Figure 3-9. Statewide residential gas energy use (RASS 2004)

Nationwide, market shares of gas and electric water heaters are nearly equal. According to *Appliance Magazine* (Appliance 2006; De Winter 2005), gas-fired water heaters accounted for 52% of U.S. shipments in 2005, and electric units accounted for 48%. These shares have remained relatively constant over time; since 1977, the gas market share has ranged from a low of 50% to a high of 56%. Figure 3-10 presents the national quantities of gas and electric water heaters shipped annually since 1977.

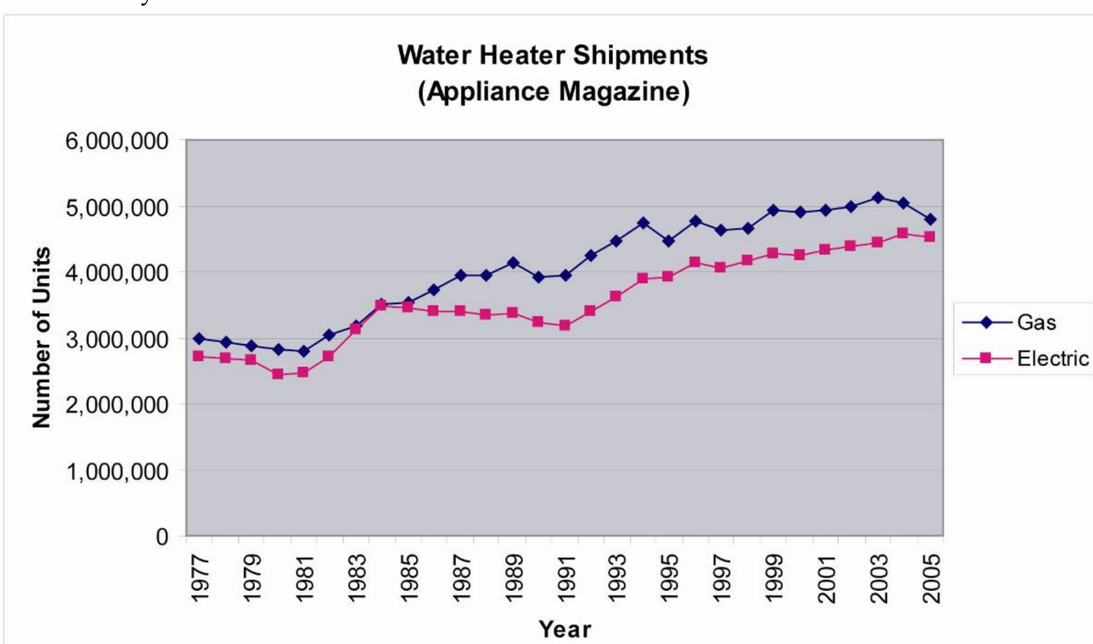

Figure 3-10. National shipments of gas and electric water heaters (Appliance Magazine 2006; De Winter 2005)

In California, the market is weighted much more heavily toward gas as 79% of all residences and 89% of single-family homes in the state have gas water heaters (Figure 3-11 and Figure 3-12). Gas water heating is more prevalent in new homes than in older homes. During 1979-1983, 14% of homes built in the state contained electric water heaters, only 2% of homes built between 2001–2003 do (Energy Commission 2004a).[15]

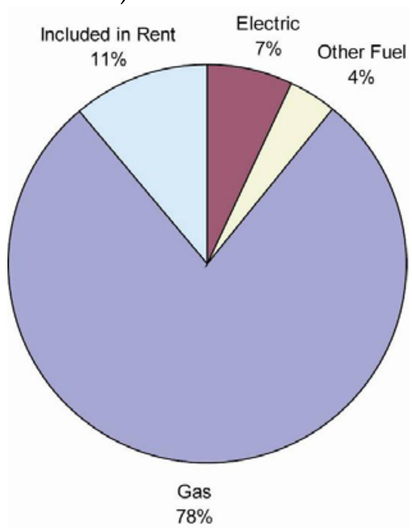

Figure 3-11. Residential water heating fuel shares in California (RASS 2004)

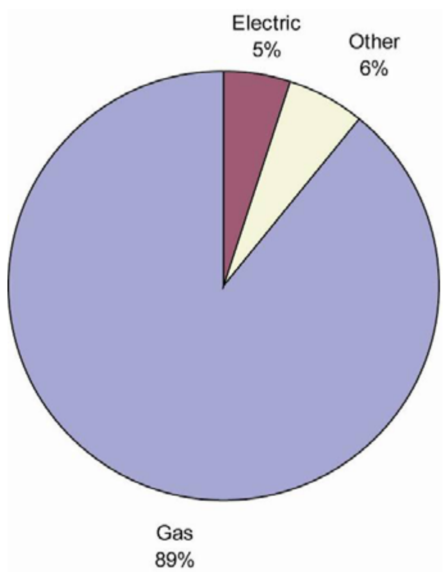

Figure 3-12. California single-family water heating fuel shares (RASS 2004)

Lifetime and Replacement Market

According to RASS, the median water heater age is in the range of 4–8 years (Banner Subset - RASS Total). The California Statewide Residential Lighting and Appliance Efficiency Saturation Study (CLASS) (RLW Analytics 2005) reports an average water heater age of 7 years. Assuming a roughly equal distribution of water heaters by age, the average water heater lifetime should

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15. This is due to implementation of Title 24 Building Energy Efficiency Standards. Since 1984, a kilowatt-hour consumed on site is counted as 10,239 Btus, three times its heat equivalent.

be about twice the age of the average operating water heater, or 10–15 years. DEER estimates that the average water heater lifetime ("Effective Useful Life"[16]) is 13 years. Similarly, the Northwest Energy Efficiency Alliance (NEEA) surveyed 286 water heater purchasers and found that the average age of water heaters at replacement was 12.9 years (NEEA 2005). However, in areas with hard water, scale buildup in water heater tanks increases the temperature on the heating surfaces covered by scale, increasing thermal stress and thus reduces the lifetime of the unit (Talbert et al. 1987).[17] Using softened water reduces scale buildup, but it causes the sacrificial anode rods to be consumed five to seven times faster, thereby hastening the corrosion of the tank itself. More research is needed on the correlation of supply water quality and unit lifetime. For SEGWHAI purposes, 13 years is used as the expected life of a tank-type water heater (with the exception of one scenario using a 20-year life for a premium, high efficiency, condensing water heater).

Given that there are more than 12 million housing units in California (U.S. Census Bureau 2000), the data provided in Figure 3-11 imply that around 10 million households in the state use gas water heaters. Since the average water heater lifetime is 13 years, about 700,000–800,000 gas units should be replaced in California each year. Actual replacement is probably closer to one million units/yr, since hard water reduces water heater lifetimes throughout much of the state. An additional 100,000–150,000 units are installed annually through new construction.

Energy Consumption and Efficiency

Unit Energy Consumption (UEC) is a measure of the average energy consumed by a type of appliance in one year. Table 3-15 presents UEC values for residential water heaters in California's utility service territories.[18] The statewide UEC is slightly higher for single-family homes (206 therms) than for multi-family homes (188 therms).[19]

[16]. Effective Useful Life is defined by the CPUC as "the median number of years that [energy efficiency] measures are still in place and operable" (CPUC 2006).

[17]. The GRI study also found that scale buildup gradually reduces gas water heater operating efficiency.

[18]. The UEC values presented in Table 3-14 were calculated by RASS using a conditional demand analysis (CDA). As shown in the table, the UEC for the SoCalGas service territory was found to be 20% higher than the UEC in the other utility territories. The cause of this difference is unknown, since the CDA methodology does not allow for a statistical analysis of cause and effect.

[19]. The Energy Information Administration's RECS provides nationwide UEC figures. 2001 RECS data (the most recent available) presents the gas water heating UEC as 197 therms, which corresponds closely to the California data presented here.

Table 3-75. Gas water heater UEC by utility (RASS 2004 Executive Summary)

Utility	Gas Water Heater UEC (therms/yr)
PG&E	183
SDG&E	181
SoCalGas	219
Statewide Average	201

CLASS reports that the average EF for 40-gallon gas water heaters was 0.58 in 2005 (including all installed water heaters, not just new installations). This is a slight increase from the 2000 average of 0.56 (RLW Analytics 2005). This efficiency increase may be a result of the 2004 National Appliance Energy Conservation Act Standards (NAECAS), which required minimum gas water heater efficiencies of 0.594 for 40-gallon units and 0.575 for 50-gallon units. However, considering the 13-year average water heater lifetime, it is surprising that the 2004 standards have already had such a significant effect and 0.58 may be an optimistic value.

DEER provides estimates of the cost and energy savings associated with upgrading to more efficient appliances. In the case of storage gas water heaters, DEER defines "high efficiency" products as those with an EF of 0.63, compared to a baseline of 0.60.[20] Depending on climate (which affects the inlet water temperature and thus energy input required), these more efficient water heaters are reported in DEER to save between 8.3–11.2 therms/yr at an incremental cost of $175. Assuming a 13-year lifetime and a discount rate of 5%, this corresponds to a cost of $1.66–$2.24 per therm saved. However, a site survey of retail water heater prices at two discount retailers reveals that DEER may overestimate the incremental cost of efficient water heaters. When the survey was executed, thirteen 40- or 50-gallon water heater models were available at the two stores. The prices and EFs of these units are depicted in Figure 3-13. As this figure indicates, there is no clear relationship between EF and price; in fact, the unit with the highest EF (0.63) has among the lowest prices. Among 50-gallon units, the water heater with the highest EF (0.61) does have the highest price; however, this unit also has other desirable features such as a slightly higher recovery rate and a stainless steel look. Therefore, the incremental price attributable to the higher EF must be less than the $80 price difference between this unit and the second most expensive 50-gallon unit. The DEER incremental price estimate of $175 is clearly too high; according to this data, the actual incremental price of more efficient water heaters is well under $100, and probably closer to $0. However, while moving from EF 0.60 to EF 0.63 involves incremental changes that can be achieved at negligible cost, further increasing EF to 0.70 and beyond (the goal of SEGWHAI) will involve more significant technical changes and more substantial incremental costs.

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20. "Baseline" here refers to the average EF of new water heaters on the market. This is slightly higher than the 0.58 average EF of installed water heaters (sometimes called "stock").

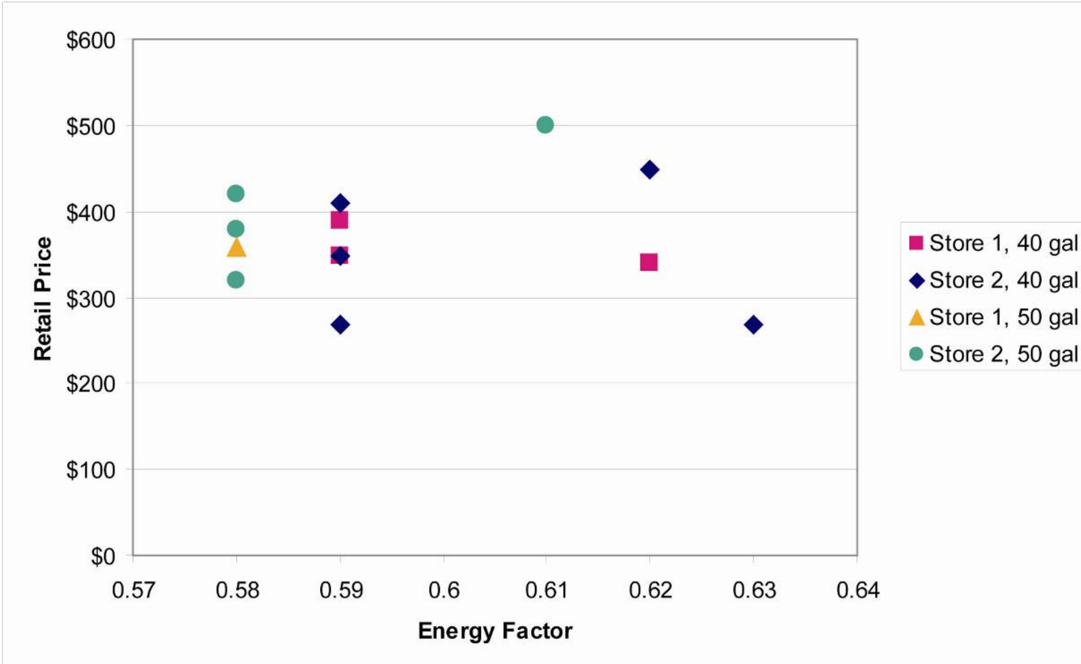

Figure 3-13. Water heater EF and retail price at two discount retailers

As an alternate explanation of pricing, much of the price variation observed among 40- and 50-gallon water heaters at the discount retail stores (such as Home Depot and Lowes) can be explained by differences in warranty rather than EF. Figure 3-14 shows that although there is some price variation at each warranty level, the correlation between price and warranty is clear. What is not clear is whether there are underlying technology differences that correlated with warranty length.

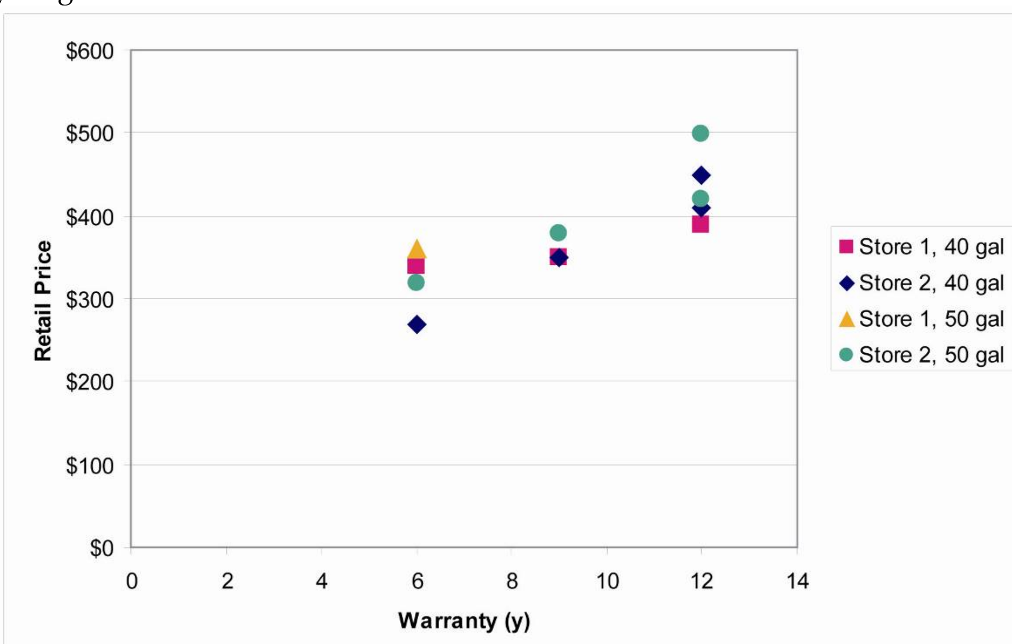

Figure 3-14. Water heater warranty and retail price at two discount retailers

Tankless Water Heaters

Tankless water heaters are common in Europe and Japan, but are relatively uncommon in the United States. According to RASS, tankless water heaters are used in only about 2% of California households (Energy Commission 2004a).[21] They have significantly higher (lab-based) efficiency ratings than conventional storage water heaters. According to the GAMA directory (GAMA 2006), most tankless ("instantaneous") gas water heaters have EFs in the 0.80–0.82 range. However, they are also much more expensive than conventional products; discount retailers sell whole-house gas tankless water heaters for approximately $1000. The higher cost of tankless products is partially offset by the federal Energy Incentives Act of 2005, which provides for tax credits of up to $300 per unit for gas water heaters with EF ≥0.80.

3.2.3 Structure of the Market

Manufacturers

Since the acquisition of American Water Heater by A.O. Smith Corporation in April 2006, there remain only three major manufacturers of residential water heaters in the United States: A.O. Smith Water Products Company, Rheem-Ruud Water Heating, and Bradford White Corporation. These three manufacturers produce 99% of the tank water heaters sold in the United States (NEEA 2005) under a variety of brand names. Table 3-16 presents the NEEA's 2005 market share estimates prior to A.O. Smith Corporation's acquisition, and the corresponding post-acquisition market shares. As a result of the acquisition, A.O. Smith Water Heating Products Company has surpassed Rheem-Ruud Water Heating to become the largest water heater manufacturer in the country, with a 42% market share.

Table 3-86. U.S. tank water heater manufacturer market shares

Manufacturer	2005 Market Share	2006 Market Share (Post-Acquisition)
Rheem-Ruud Water Heating	40%	40%
A.O. Smith-State Ind.	25%	42%
American Water Heater Company	17%	-
Bradford White Corporation	17%	17%
Other Manufacturers	1%	1%
Total Standard Tank Market	**100%**	**100%**

None of the major U.S. water heater manufacturers produce tankless water heaters domestically, though some sell foreign-made tankless products.

Distributors, Wholesalers, Retailers

As of 2000, approximately half of water heaters shipped nationwide were sold by large retailers such as The Home Depot and Lowe's, where they were bought by both plumbers and homeowners. The other half were sold by manufacturers to plumbing wholesalers, who then sold them to plumbers (Figure 3-15). More recent data are not available, but the trend is probably toward increasing sales by the large retailers who supply replacement units. The distribution market is quite competitive; in the Northwest, at least, no single distributor makes up more than 10% of distribution sales (NEEA 2005).

[21]. 1.7% of California households use gas-fired tankless water heaters, and 0.3% use electric tankless units.

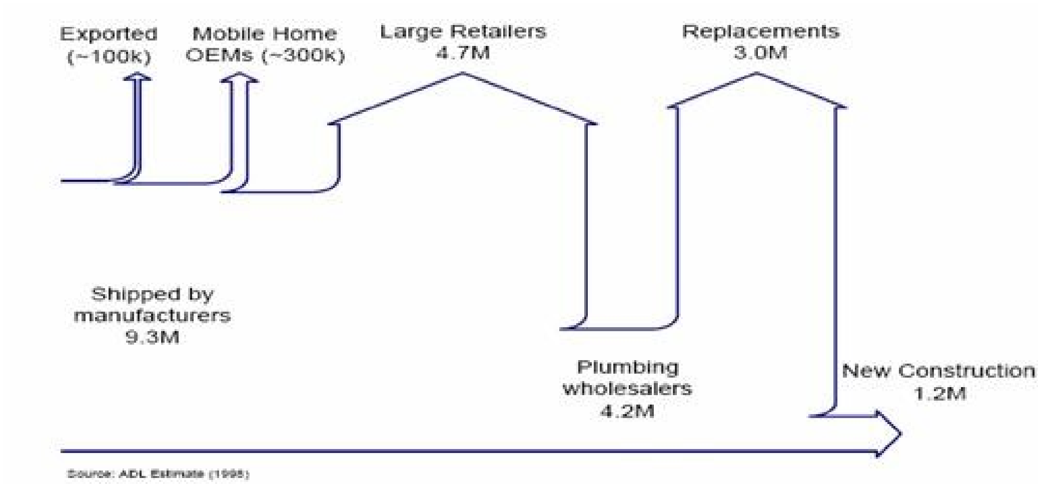

Figure 3-15. Water heater market distribution channels (U.S. DOE 2000)

Installers

NEEA surveyed nine water heater installers (mostly independent plumbing contractors) in the northwestern United States (NEEA 2005). Most installers surveyed reported that they install between 50–1000 water heaters annually, and that water heaters account for 5–15% of company business. The most common means of marketing their services was the phone book, and 50% of installers stated that most of their business is generated by their listing in the yellow pages. NEEA also obtained installation cost estimates from six installers (see Section 3.2.4 Installed Water Heater Costs).

To extend the NEEA survey and investigate the California market, the SEGWHAI team surveyed dozens of water heater installers in Sacramento, Bakersfield, and Los Angeles. These cities were chosen because they represent different areas of the state as well as different gas utilities: Sacramento is supplied by PG&E, Los Angeles by SoCalGas, and Bakersfield by both of these utilities. Using the yellow pages in each city, the team called 20–30% of the companies listed under "Plumbers" and/or "Water Heaters." 30–50% of those called agreed to participate in the survey (Table 3-17). Most companies surveyed were independent plumbing contractors, but a small number were branches of large businesses such as The Home Depot.

Table 3-97. Plumbers and water heater companies

Market	Plumbers/Water Heater Companies in Yellow Pages	Number Contacted (% of total)	Number of Participants (% of those contacted)
Sacramento	195	52 (27%)	20 (38%)
Bakersfield	104	24 (23%)	11 (46%)
Los Angeles	313	64 (20%)	21 (33%)

The team asked survey participants a number of questions about water heater installation costs and company characteristics (Table 3-18).

Table 3-108. Water heater installer survey questions

Question Number	Question
1	How many water heaters does your company install per year?
2	What % of your total sales does water heater business account for?
3	Do you offer 24-hour service?
4	Does your utility offer a rebate for higher efficiency models? If so, do you inform customers of the rebate?
5	How long is the warranty for materials? Labor?
6	What water heater brands do you sell?
7	What is the installation cost (labor plus materials) for a 40-gallon residential water heater?
8	What is the labor/materials cost breakdown?
9	Are there additional charges for disposal of old water heater? Building permit? Bringing the site up to code?

Responses to questions 1 and 2 are presented in Table 3-19. The team was unable to obtain installation volume estimates from the large businesses that were surveyed.

Table 3-19. Responses to questions 1 and 2

Question Number	Topic	Number of responses	Minimum	Maximum	Mean
1	Number of water heaters installed/yr	14	4	400	154
2	% of total business	12	1%	50%	14%

Responses to questions 3 and 4 are presented in Table 3-20. Question 4 is particularly interesting: of the 13 respondents, 9 either did not know whether their utility offered a rebate for efficient water heaters, or believed (mistakenly) that it did not offer such a rebate. Only four installers were correct in stating that a rebate was available; and just one of these reported informing customers of the rebate.

Table 3-20. Responses to questions 3 and 4

Question Number	Topic	Number of responses	Yes	No	Don't know
3	24-hour service	15	60%	40%	-
4	Rebate	13	31%	15%	54%

Most installers reported that the manufacturer warranties for water heaters were 6–10 years. The most common reported warranty for labor was one year (the minimum required by state law).

The water heater brands that were mentioned most often by installers were Bradford White and American. Other brands mentioned were GE (made by Rheem), Rheem-Ruud, A.O. Smith, Whirlpool (made by A.O. Smith), and State (also made by A.O. Smith).

Responses to Questions 7–9 (water heater costs) will be discussed in Section 3.2.4 Installed Water Heater Costs.

Customers

NEEA surveyed 286 recent water heater purchasers in the states of Washington, Oregon, Idaho, and Montana (NEEA 2005). They found that the average age of replaced water heaters was 12.9 years, which corresponds closely with the DEER water heater lifetime estimate of 13 years. According to the survey, 32% of water heaters were replaced before they failed, 41% were replaced after failing suddenly, and 26% were replaced after non-sudden failure. Over 89% of customers reported installing standard tank water heaters, with an average volume of about 50 gallons. The average volume of electric units (53 gallons) was slightly higher than the average volume of gas units (49 gallons).[22] Approximately 52% of customers installed their new water heater themselves and customers who purchased electric units more frequently installed new units themselves. About half of consumers considered only one water heater before their purchase.

Approximately 35% of consumers bought water heaters at a national home improvement store chain. Most other consumers bought water heaters through a contractor or plumber (25%), at a plumbing supply store (15%), or at a hardware store (14%). Most customers reported buying water heaters made by A.O. Smith (36%) or Rheem/Ruud (32%). Other major manufacturer market shares were American (18%) and Bradford White (8%). At the time of the survey, American had not yet been acquired by A.O. Smith.

Unlike in California where gas water heaters are much more common than electric water heaters, 57% of Northwest consumers reported buying electric units. This is primarily the result of lower electricity rates in the Northwest. In addition, building codes in the Northwest do not require the use of a *source multiplier* in determining electric appliance energy budget. This failure to take into account the imperfect efficiency of electricity generation amounts to favoring electric appliances over gas appliances.[23]

The NEEA consumer survey also measured consumers' willingness to pay for more efficient water heaters; 32% of gas water heater consumers indicated that they would be willing to pay more for a tankless water heater that provided $75 in annual gas savings and provided unlimited hot water. On average, these consumers said that they would be willing to pay an additional $247 for this unit and 12% of respondents said that they would be "very likely" to purchase the tankless unit even if its incremental cost was $500.

3.2.4 Installed Water Heater Costs

NEEA Survey

In their survey of water heater installers, NEEA obtained cost estimates for materials and installation of gas water heaters. These estimates ranged from $350–$1,100, with an average cost of $637.

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[22]. Electric water heaters have lower recovery rates than gas water heaters, so electric tank sizes tend to be larger.

[23]. However, due to the widespread utilization of hydroelectricity in the Northwest, use of a source multiplier is less crucial there than it is in California.

In the NEEA consumer survey, consumers reported paying an average of $581 for new gas water heaters, including installation. Averages were $409 for consumers who installed their units themselves and $648 for consumers who used a contractor (NEEA 2005).

SEGWHAI Survey

A survey of water heater installers in Sacramento, Bakersfield, and Los Angeles found that the average installation cost (including materials) for a 40-gallon water heater was $865. Figure 3-16 shows the range of cost estimates received.

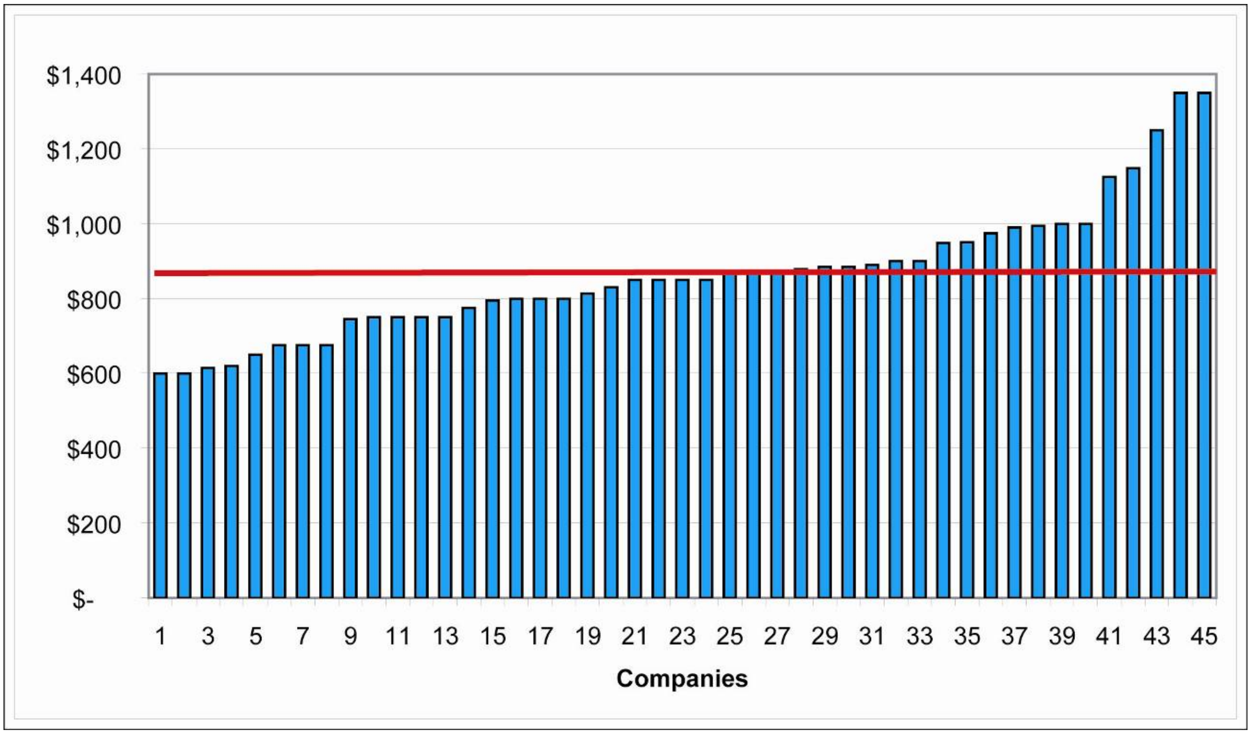

Figure 3-16. Installed costs for 40-gallon residential water heaters in Sacramento, Bakersfield, and Los Angeles. Average is indicated by the red line.

Averages varied significantly across the three cities. In Sacramento, the average cost estimate was $972; in Bakersfield, $750; and in Los Angeles, $802. According to the installers, additional costs include:

- Disposal of the old water heater: ≤$40
- Building permit (varies by city): $40–$120
- Bringing the site up to code: ≤$400

The latter factor is probably responsible for much of the variation in cost estimates obtained.

Cost Breakdown

In the SEGWHAI survey, installers claimed that about 60% of installation costs are for materials and 40% is for labor. Labor cost estimates were in the $200–$400 range. This breakdown is the reverse of the nationwide U.S. DOE study results (Figure 3-17), which found that about 60% of the price of a water heater is the installation cost (with markup), and 16% goes toward the materials (U.S. DOE 2000). This corresponds closely with the results of the NEEA survey, which found that an average of 44% of the average gas water heater cost was for materials, and the remainder for installation (NEEA 2005).

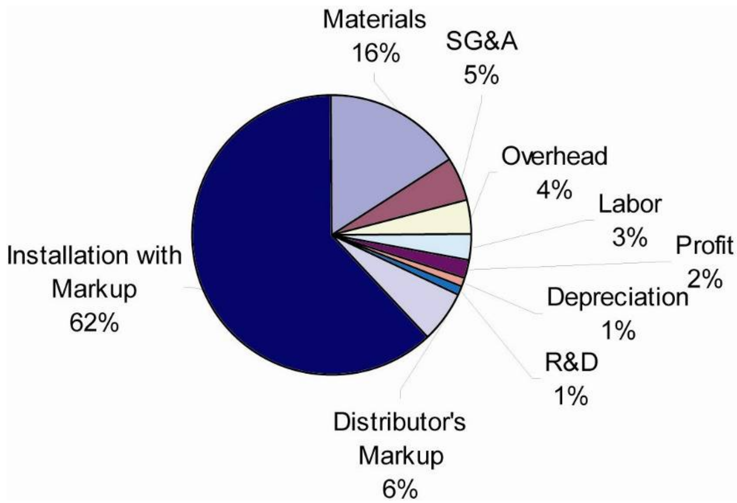

Figure 3-17. Breakdown of storage water heater installed cost (U.S. DOE 2000)

It may be that installers that participated in the SEGWHAI survey tended to include their markup in the "materials" portion of the price, rather than the "installation" portion. In that case, these results would be consistent with the U.S. DOE results price breakdown if the "installation with markup" section of Figure 3-17 is made up of approximately two-thirds installation, and one-third markup. The U.S. DOE study acknowledges a wide range of contractor markups: from 31%–59% (Figure 3-18) (U.S. DOE 2000).

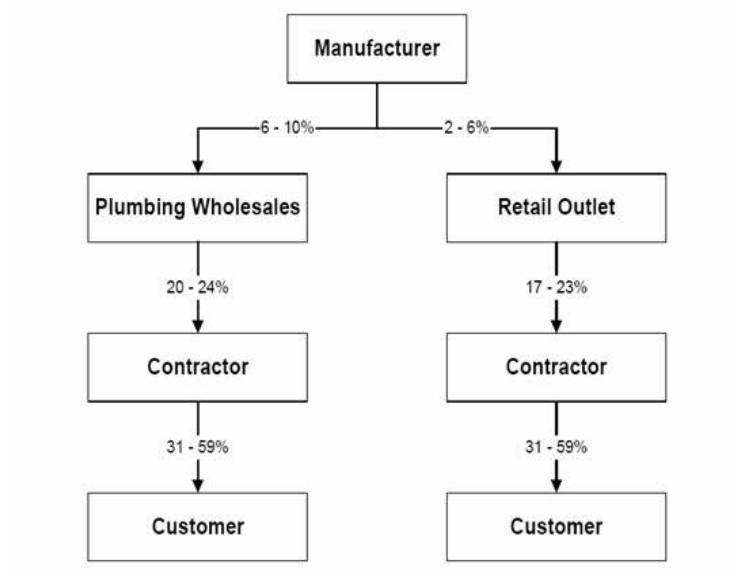

Figure 3-18. Typical markups for residential water heaters (U.S. DOE 2000)

3.2.5 California Water Heater Field Survey

Amaro Construction Services carried out a field survey of 181 water heater installations in California for the SEGWHAI project. They collected information on water heater locations, capacities, estimated ages, and details regarding insulation, flue, natural gas line sizing, and other unit characteristics. This information is useful in estimating the potential market share for SEGWHAI units that may require electricity, condensate drainage, and a new flue for their installation. A complete list of survey questions is presented in Appendix A (APA-1). Survey results can be divided into two categories by age of home: 93 are new (built in 2003 or later), and 88 are older (built 1950–1996).[24] The data collected is not intended to be representative of the California market, but does provide key information on water heater installation characteristics. In the tables below, percentages do not all add up to 100 because a complete set of data was not obtained from each site.

The survey-wide average water heater age is five years, and the average home was built in 1990 (Table 3-21).

Table 3-111. Average home and water heater age from California field survey

	Average Home Age (years)	Average Water Heater Age (years)
New Homes	1	1
Older Homes	31	9
All	16	5

Average water heater tank volume is 46 gallons. The majority of sites surveyed (57%) had 50-gallon water heaters. Older homes tend to have smaller units than the new homes (Figure 3-19). Six of the new homes surveyed utilize tankless water heaters.

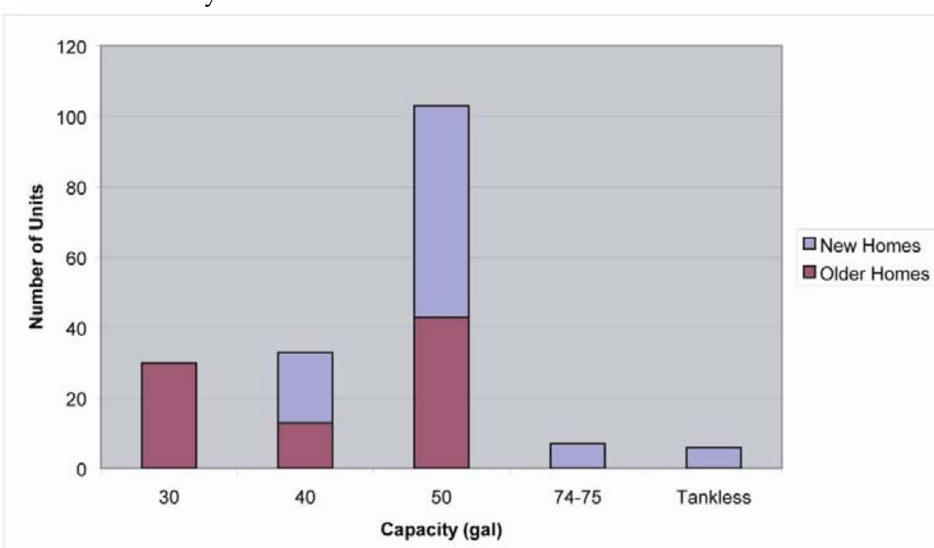

Figure 3-19. Water heater volume by age of home

[24]. By chance, no homes built between 1996 and 2003 appeared in the survey.

The survey shows that most water heaters are installed in garages. This is especially true of new homes (Table 3-22).

Table 3-122. Water heater location

	Water Heater Location		
	Garage	Laundry Room or Kitchen	Closet
New Homes	84%	0%	4%
Older Homes	69%	17%	7%
All	77%	9%	6%

Most water heater gas lines are ½", and most burner capacities are 40,000 Btuh. Gas input capacity data were not obtained at many older homes, since this information was often obscured by a water heater blanket.

At 93% of sites, the flue was naturally vented, 10 homes had direct vents (venting by-products directly outside), and one employed a power vent. Over 71% of sites had three inch diameter flues, with most of the remainder being four inches. Most flues had draft diverters and were connected to a separate (rather than shared) stack. Nearly half of new homes had flexible metal flues that could be bent into curves, rather than requiring elbows to change direction (Table 3-23). All sites had temperature/pressure relief valves, which were plumbed to the outside in nearly all cases.

Table 3-133. Flue material

	Flue			
	Single Wall Metal	Dual Wall Metal	Single/Dual Wall Metal	Flexible
New Homes	35%	34%	2%	45%
Older Homes	67%	24%	0%	6%
All	51%	29%	1%	26%

Average distances between the water heater and other points of interest are presented in Table 3-24.

Table 3-144. Measurements from water heater

	Distance to gas meter (ft)	Distance to ¾" gas line (ft)	Distance to 110 V outlet (ft)	Run to 110 V outlet across wall/ceiling (ft)
New Home Average	23	21	11	17
Older Home Average	21	19	10	15
Overall Average	22	20	10	16

Other information obtained from the field survey is shown below:

- Rust was observed on the plumbing, tank, or vent pipe at 10 older sites.
- Most common brands: State/State Select, Bradford White, and Rheem/Ruud. Other brands observed at multiple sites: Sears, A.O. Smith, GE, Rinnai (tankless), Takagi (tankless), Frama.

- Cold water inlet and hot water outlet pipes are ¾" at all but one site. Cold water inlets include shut-off valves in all but one case, but very few hot water outlets include shut-off valves. Most water pipes are flexible.
- At nearly all sites for which this information was available, a condensate line could be run directly outside.
- Among the 181 sites, the surveyors noticed 134 obvious code or safety violations. Most of these violations were water heaters installed in garages lacking protective bollards. Other violations included water heaters that lacked earthquake straps, flammable materials stored within one ft of the unit, and units in garages not installed on a platform higher than 18 inches above the floor.
- Drain pans were observed at 13% of the older homes and 31% of the new homes; 11 drain pans were plumbed to the outside.
- Termination: flues go through the roof in the clear at all but 10 of the sites for which this information was obtained.

3.2.6 Recommendations for Future Market Research

The SEGWHAI team recommends a more detailed assessment of the California and North American water heating markets. This assessment should be a larger-scale version of the Amaro field survey, and should include water heater temperature settings as well as technical specifications of installed water heaters and details of the sites (availability of electricity, size of gas line, etc.). The survey should be done using a stratified sampling methodology and achieve statistically significant results in each installation category. Possible categories include age of home, age of water heater, water heater location, and size of the hot water load as indicated by dwelling size and/or occupancy. In addition, short-term monitoring of hot water end-uses would be useful at a subset of surveyed locations. Such an assessment would assist water heater manufacturers in determining the potential market for efficient products of various types and assist utilities in designing effective incentive programs.

3.3 Manufacturer Interest & Capabilities

3.3.1 Overview

In recent years, water heater manufacturers have met a number of technology challenges imposed by changing regulations. Manufacturers follow a multistage product development process to ensure the safety and performance of new products. SEGWHAI surveyed U.S. manufacturers of gas storage water heaters with respect to their future plans and interest in SEGWHAI. Survey responses were encouraging, and although manufacturers did not provide detailed information regarding timing or expected costs of SEGWHAI products, they expressed interest in SEGWHAI plans for field testing and incentives for both non-condensing and condensing water heaters.

3.3.2 Technology Challenges

Changing regulations have required manufacturers to meet a number of technological challenges over the past few years. Manufacturers have successfully changed their insulation blowing agent, incorporated FVIR design, and increased their baseline product efficiency. They have also made significant progress toward reducing the NO_X emissions of water heaters sold in Southern California. These accomplishments have required significant technological advances and have been achieved even though research and development activities have accounted for only about 2% of water heater manufacturing costs (U.S. DOE 2000).

Insulation Blowing Agent

Modern conventional water heaters are insulated with foam, which is blown into the space between the water heater tank and jacket using a chemical blowing agent. Until recently, manufacturers used HCFC-141b, an ozone-depleting substance, as a blowing agent. In 2003, the U.S. EPA banned all U.S. production and importation of HCFC-141b in response to the Montreal Protocol on Substances that Deplete the Ozone Layer (U.S. EPA 2006). There are a number of potential replacements for HCFC-141b, including hydrofluorocarbons, pentane/cyclopentane, and water-based blowing agents. All water heater manufacturers have complied with the ban on HCFC-141b.

FVIR Design

Water heaters are often installed in garages and basements where flammable liquids (such as gasoline and paint thinners) may be present. Conventional gas water heaters rely on a standing pilot, and therefore must be designed to avoid the unintended ignition of flammable vapors (U.S. DOE 2000). All conventional, atmospherically vented ≤50-gallon gas water heaters have been subject to voluntary FVIR safety standards since July 1, 2003.[25] Power vent models that are ≤50 gallons have been subject to the standard since July 1, 2006, and other water heaters (all > 50-gallon models, and ≤50-gallon direct vent/direct power vent models) were subject to the standard beginning January 1, 2007. FVIR water heaters are designed to sense the ignition of flammable vapors and respond by shutting off the pilot light and keeping burning vapors inside the combustion chamber until they have burned out (GAMA 2005). All water heater manufacturers have complied with the FVIR standards.

Revised Efficiency Standards

The 1986 National Appliance Energy Conservation Act (NAECA) implemented the first national appliance efficiency standards. The U.S. DOE revised the NAECA water heater standards in 2001. The new gas storage water heater EF standard, which took effect in January 2004, defines the minimum EF as shown below:

- EF ≥0.67 – (0.0019 x Rated Storage Volume in gallons)

This standard corresponds to EF ≥0.594 for 40-gallon products, and EF ≥0.575 for 50-gallon products. Water heater manufacturers have successfully met the new efficiency standards. According to the GAMA directory of water heater models (2006), about half of the residential gas 40- and 50-gallon models are at the minimum efficiency level, and the rest are more efficient, with EFs ranging from 0.60–0.67. Distribution of sales is assumed to be dominated by minimally efficient units.

NO_X Requirements

SCAQMD's Rule 1121 requires that beginning in July 2007, all ≤50-gallon water heaters sold in the SCAQMD emit no more than 10 ng/J of NO_X of heat output (SCAQMD 2004).[26] In October 2006, the major U.S. water heater manufacturers testified before the SCAQMD Hearing Board on their progress toward meeting this requirement. Despite significant technical challenges, all three manufacturers have made substantial progress toward developing what they call ultra low NO_X (ULN) products. One manufacturer will be ready to supply ULN products beginning in July 2007, and the other two manufacturers will have products available in October 2007. The three manufacturers jointly requested that the Hearing Board grant them a three-month extension to October. If some manufacturers have more difficulty meeting the deadline than others, their respective market shares may be affected.

3.3.3 Product Development Process

In order to meet each of the technical challenges discussed above, manufacturers have gone through a multi-stage product development process. Each significant product change requires

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[25]. Compliance with the FVIR standards is necessary for water heaters to be certified through American National Standards Institute (ANSI). Though the ANSI standards are voluntary, all water heater manufacturers comply with them for liability reasons.

[26]. For background on Rule 1121, see Section 3.0 Energy and Environmental Benefits.

extensive testing to verify performance, safety, and reliability. For example, one major manufacturer follows a six-stage product design process, as outlined below (SCAQMD 2006b):

- Preliminary Investigation
- Technical Feasibility
- Product/Process Design
- Product/Process Verification
- Design and Process Verification
- Production Market Launch

This process generally takes several years to complete. In some cases, it could be accelerated with additional funding and effort.

3.3.4 Manufacturer Issues and Perspectives

Manufacturer Participation

Manufacturer interest in SEGWHAI is demonstrated by the fact that representatives of the three major U.S. water heater manufacturers, as well as some smaller manufacturers, have participated in the SEGWHAI Steering committee. In addition, GAMA has participated on behalf of its members. Manufacturer representatives on the Steering committee have shared their perspectives on the design of future SEGWHAI phases, including prototype development funding, emerging technology testing, and incentive programs.

In fall 2006, SEGWHAI surveyed manufacturers of gas water heaters with respect to their future plans and interest in SEGWHAI. The survey was distributed by GAMA, which then provided SEGWHAI with aggregated results to protect manufacturer anonymity. GAMA received survey responses from every major manufacturer of storage gas water heaters in the United States. Survey questions and compiled responses are presented in Appendix B (APB-1) and are discussed in the following sections. Survey developers did not expect manufacturers to be willing or able to answer all of the questions posed. Indeed, the survey was designed to both gather information and increase awareness of and interest in SEGWHAI among GAMA members. In the survey, minimum proposed SEGWHAI EF levels were presented as 0.68 for Tier 1 and 0.80 for Tier 2 products. Since the survey was conducted, the SEGWHAI steering committee has increased these goals to 0.70 and 0.82, respectively (see Section 4.1 SEGWHAI Technical Specifications).

Timing

As anticipated, manufacturers did not provide information regarding when they are planning to introduce more efficient storage gas water heaters (in the absence of SEGWHAI support) or when they could have products available to participate in SEGWHAI pilot or mass market programs. Respondents were hesitant to release this sensitive information since there are so few players in the market that even in aggregate form, the survey results could allow manufacturers to infer the responses of their competitors.

Prototyping and Field Testing

Manufacturers expressed some interest in SEGWHAI prototype R&D funding for condensing (EF ≥0.80) products. They expressed more interest in participating in an emerging technology field demonstration of both EF ≥0.68 and EF ≥0.80 products. They indicated that a representative field test should include 50–200 units per model. The survey did not ask respondents to specify the number of units more precisely; however, GAMA representative Frank Stanonik speculates that 50–100 units per model would be sufficient.

Prototype funding for advanced gas water heater development has been successful in the past. For instance, U.S. DOE prototype funding led to the development of an innovative condensing water heater that was introduced to market by a major manufacturer in April 2006. The product, which is directed at commercial applications as well as residential combined space/water heating, was developed and commercialized through collaboration among three entities; the Gas Technology Institute (GTI), a leading product development company, and the manufacturer.

Incentives

All survey respondents agreed that the most effective incentive programs are those aimed at consumers, rather than upstream market participants. This is in line with their observation, expressed at SEGWHAI Steering committee meetings, that only the lowest-cost water heaters are demanded by customers and that there is no proven market for more expensive models.[27] Manufacturers indicated that the most effective programs to promote high efficiency water heaters would be ENERGY STAR* branding, customer rebates, tax credits, and the creation of market demand for more expensive and efficient models. Less effective programs include third-party field and laboratory testing, rebates for discount retailers, and rebates for manufacturers themselves. These responses contrast with the experiences of PG&E and SoCalGas, where upstream incentive programs have been quite successful. For example, Robert Mowris & Associates (2004) analyzed a 2002–2003 program that provided incentives of $10/unit to wholesalers in the PG&E service territory for stocking gas water heaters with EF ≥0.61. From the $10 incentive, $3 was kept by the wholesaler, and $7 was passed along as a discount to the plumber. The program provided incentives for more than 35,000 heaters, and its cost-effectiveness (based on the TRC test) was 4.35. Programs with values ≥1 are considered cost-effective, and a value of 4.35 indicates a highly cost-effective program.

Manufacturers expressed interest in producing EF ≥0.68 products for customer incentives of $80 per unit and EF ≥0.80 products for $200 per unit, though one manufacturer indicated that higher incentives would be to cover the incremental costs of these products. It is unclear which manufacturers expect the incremental production costs of these products to be below $80 and $200, respectively.

Manufacturers stated that permanent transformation of the water heater market would require incentives for at least 50,000 high efficiency units/yr, divided among all manufacturers, and that the incentives would need to be available for at least five years.

The case of electric heat pump water heaters illustrates the need for incentive programs to be large-scale, continuous, multi-year efforts. Heat pump water heaters are two to three times

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[27]. As mentioned in Section 3.3.2 Technology Challenges water heater manufacturers make and sell many models that are above the minimum EF. However, consumers that choose higher efficiency products may do so not because of their efficiency per se, but because they include better warranties or offer other advantages (see Section 3.2 California's Small Gas Storage Water Heater Market).

more efficient than conventional electric water heaters, but despite having received extensive R&D support over several decades, they are still struggling to be commercially viable. This is due, in part, to the fact the early incentive programs were insufficient in duration for major manufacturers to commit to large-scale production efforts. Recent longer-term efforts in Connecticut were structured to address this problem. However, major manufacturers were not involved, and units were supplied by several small companies in quantities that did not allow for economies of scale or sufficiently high levels of quality control and product reliability. Those smaller manufacturers could not afford to subsidize their product while making improvements over several years, and could not count on continuing product development incentives from conservation programs.[28]

NO_X Issues

Manufacturers did not disclose how long it would take them to develop a Rule 1121 compliant SEGWHAI water heater, or how much Rule 1121 compliance would add to the cost of a SEGWHAI product. At the SCAQMD hearing in October, one manufacturer projected that Rule 1121 compliant products will cost the consumer $125 more than currently available baseline products. As experience is gained with low NO_X products and their production scale increases, this incremental cost is likely to decrease.[29]

Survey respondents expressed minimal interest in prototype R&D funding for Rule 1121 products, presumably because they have nearly completed development of these products. They stated that the EF level of their initial Rule 1121-compliant 40-gallon water heater will be in the range of 0.60–0.63, which is just above the NAECA standard of 0.594. Their Rule 1121 models will have the same venting requirements as existing units. They did not provide information regarding the electric power requirements of their Rule 1121 products. However, at the SCAQMD hearing, one manufacturer presented a photograph of a prototype device that plugs into a 110 V outlet, which they plan to use in their Rule 1121 products to meet Lint, Dust, and Oil (LDO) standards (SCAQMD 2006c).

Capability

Survey respondents were reluctant to provide concrete information on their product development plans. However, manufacturers have not claimed that SEGWHAI water heaters are impossible to make, which suggests that they anticipate being able to develop these products. Though they are hesitant to provide information on the projected costs of SEGWHAI products, some information can be deduced from their stated interest in consumer incentives of $80 for EF 0.68 products and $200 for EF 0.80 products. On the whole, manufacturers' responses to the survey suggest that they are willing and able to participate in SEGWHAI. Confidential discussions with manufacturers will be necessary to determine how quickly SEGWHAI products can be developed.

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[28]. Russ Johnson of Johnson Research, LLC provided information on heat pump water heaters.

[29]. As discussed in Section 3.4 Roadmap for Commercialization, Outreach, and Marketing, manufacturing costs tend to decrease with increasing production scale and manufacturing experience. This has been observed in a number of industries.

3.4 Roadmap for Commercialization, Outreach and Marketing

3.4.1 Overview

For SEGWHAI compliant units to succeed in the market, SEGWHAI will need to be embraced at all points in the distribution chain, from manufacturers to consumers. Consumers value energy efficiency and environmental benefits, but most are reluctant to pay a significantly higher purchase price for those benefits. Therefore, program implementers will need to work to reduce the incremental cost of products to consumers through rebates, tax credits, and financing programs. Product prices will also come down as manufacturers increase the scale of production, which they will do in response to increased consumer demand as well as manufacturer incentives such as tax credits. Evidence suggests that manufacturers have the technical ability to develop products meeting SEGWHAI criteria, and some strategies are available to enhance that ability. Future implementers of SEGWHAI criteria should also work with ENERGY STAR* in developing a water heater program, since ENERGY STAR* branding will increase consumer awareness of and confidence in products compliant with SEGWHAI criteria. Wholesalers and retailers can be encouraged to stock and sell SEGWHAI compliant water heaters through the use of upstream incentives. Lessons from previous energy efficiency programs have been used to inform possible future activities.

3.4.2 Consumers

Water heaters that meet SEGWHAI criteria will not be successful in the market unless consumers are motivated to purchase them, wholesalers and retailers are motivated to stock and sell them, and manufacturers are motivated to produce them on a large scale at a price point that is attractive to customers. The current stance of consumers, and strategies to increase their motivation, are discussed in this section. Wholesalers/retailers and manufacturers are addressed in the following sections.

The water heating market is a commodity market, and most residential water heaters purchased are 40- to 50-gallon gas or electric storage products with efficiencies close to the federal minimum efficiency standards.[30] Most consumers consider only one or two products before choosing a new unit (NEEA 2006). Residential water heater purchases are driven by the following four factors (U.S. DOE 2005):

- Purchase Price
- Availability
- Familiarity
- Energy Efficiency

Low purchase price is important to consumers of all products, but is especially significant to water heater purchasers. This is due to the fact that most water heaters are bought upon the failure of the previous unit,[31] so consumers do not anticipate water heater failure and thus do not plan for the associated replacement cost. In addition, in order to minimize time spent without hot water when their old unit fails, consumers prefer water heaters that are

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30. As discussed in Section 3.2 California's Small Gas Storage Water Heater Market, water heater price is a function of warranty, but there is no clear relationship between price and efficiency.

31. In their survey of 286 recent water heater purchasers, the NEEA (2006) found that more than two-thirds of consumers purchased a new water heater after the failure of their old unit.

immediately available. Consumers tend to prefer familiar products in all types of purchases, but especially so in the case of essential (but invisible) services such as water heating. Moreover, many consumers buy water heaters through plumbers, and plumbers tend to choose low-cost, universally stocked products as a business strategy. As shown in the SEGWHAI market survey (see Section 3.2 California's Small Gas Storage Water Heater Market), plumbers have little knowledge of available incentives, and often do not offer high efficiency products to their customers.[32]

Though consumers report that water heater efficiency/operating cost is important to them,[33] their behavior indicates that most are not willing to pay a significantly higher upfront cost to obtain increased efficiency. Studies have found that consumers often choose not to purchase efficient products that have incremental upfront costs, even if those products would save them money in the long term (Sanstad et al. 2006). This appears to be especially true in the case of water heaters where efficient products are not immediately available.

A small fraction of consumers have recently begun to choose high cost, high efficiency tankless water heaters,[34] but these purchases are not based solely on efficiency. These consumers often purchase these tankless products as they offer additional advantages such as "unlimited" hot water and smaller product size.[35] Manufacturers have also recently begun to offer relatively high cost, high efficiency commercial condensing water heaters. Though residential condensing domestic hot water-only products are not yet available, one manufacturer recently released a condensing model at about half the price of other models in its class. Sales of this product are reported to be twice what was expected. These developments suggest the existence in the market of what Christensen et al. (2004) calls "undershot" customers; people who are willing to pay a premium for an improved water heater (the market has "undershot" their needs). Though some undershot customers are satisfied with existing tankless (or condensing) products, others probably find these too expensive. These consumers are prime candidates for SEGWHAI products.

The fact that consumers value energy efficiency is promising for the success of SEGWHAI compliant products. However, the other three drivers of residential water heater purchases (purchase cost, availability, and familiarity) all present challenges for high efficiency water

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[32]. For example, a local customer ordered an efficient water heater, which qualified for a PG&E rebate, from a company that specializes in water heater replacements. He had to wait three days without hot water for the company to get the product from the distributor. He was then charged a $300 premium for the product. Under these circumstances, it is not surprising that most customers do not choose high efficiency water heaters.

[33]. The NEEA (2006) survey found that consumers rated "energy efficiency/operating cost" as the most important factor influencing their choice of a water heater. Similarly, in a "simulated shopping" study by the ACEEE (Thorne and Egan 2002), most participants reported energy efficiency as the reason for their water heater selection. However, neither of these studies involved observations of actual purchasing behavior.

[34]. In California, 1.4% of households had a tankless water heater in 2005 (RLW Analytics 2005).

[35]. Tankless water heaters also have some disadvantages compared to conventional products: they require a flow rate of at least 0.5 gallons per minute to turn on, and have a lag time before hot water is delivered. The availability of "unlimited" hot water can also have the societal disadvantage of increasing water and energy use.

heaters of the types that the initiative promotes. When they enter the market, these products are likely to have higher purchase costs, be less widely available, and be less familiar than conventional products. In the sections below, strategies to overcome the cost and familiarity barriers are discussed. Product availability must be addressed through manufacturers, wholesalers, and retailers (Sections 3.4.3 Wholesalers, Retailers, Builders, and 3.4.4 Manufacturers). Together, these strategies will create consumer demand for SEGWHAI products.

Retail Price

Very high efficiency gas water heaters are more expensive than conventional water heaters. For instance, tankless and condensing water heaters have installed prices of approximately $2500 and $4000, respectively, with EFs in the range of 0.80–0.85, compared with installed prices of $800–$900 for conventional units (Section 3.2.4 Installed Water Heater Costs). Two tiers of SEGWHAI compliant units are proposed: Tier 1 (non-condensing) products are expected to have incremental costs of up to $200, and Tier 2 (condensing) products are expected to have incremental costs of up to $400.36.

Table 3-155. Proposed SEGWHAI EF and installed costs.

Generic Gas Water Heater Type	EF	Installed Cost
NAECA Standard	0.58	$900
SEGWHAI Tier 1	0.70	$1,110 (rebate of $200
SEGWHAI Tier 2	0.82	$1,300 (rebate of $400)
Tankless	0.80	$2,500
Large Capacity Condensing	0.84	$4,000

Because purchase price is so important to consumers, the higher cost of water heaters that meet SEGWHAI criteria must be addressed in order to create consumer demand for these products. One reason for the higher prices of efficient water heaters is simply their small market share, which prevents manufacturers from taking full advantage of economics of scale in their production. Manufacturers report that a product type needs to have sales of 50,000 units/yr to demonstrate mass market potential. Furthermore, individual manufacturer production levels of at least 100,000 units a year are needed to fully utilize a production line. In addition, with large manufacturing volumes comes manufacturing solutions that often result in cost reductions and product quality improvements. For instance, it has been observed for a number of technologies related to electric power production, including photovoltaics, that production costs decrease by about 20% for each doubling in the cumulative quantity of product shipped (United Nations Environment Programme 2000). In providing incentives for efficient products, SEGWHAI will serve as a catalyst in helping manufacturers to achieve the cost decreases associated with volume production.

Changes in the production process may allow manufacturers to reduce costs before large-scale production volumes are achieved. The manufacturers themselves must develop specific strategies, but general approaches suggested in *Solar and Efficient Water Heating: A Technology Roadmap* (U.S. DOE 2005) include using lower-cost materials, reducing labor in the production

[36]. These are the maximum incremental costs that would allow the program to proceed with a TRC of greater than 1 (see Section 3.0 Energy and Environmental Benefits).

process by designing products for ease of manufacture and investing in cost-effective automation, and sourcing components globally in order to obtain volume discounts. Finally, financing and incentive programs can enable consumers to invest in SEGWHAI-based products despite their higher upfront costs. These programs are discussed in the following sections.

Incentives

Even if the expected volume manufacturing cost reductions are realized, water heaters that meet SEGWHAI criteria will have a higher consumer purchase price than less efficient products. Rebates based on the value of the energy saved can offset this higher cost, allowing SEGWHAI products to compete more effectively with conventional water heaters. The initiative aims to make rebates from natural gas utilities and public agencies available for qualifying products until such products reach commercial maturity. In California, this type of rebate program is funded through the "public goods charge" on residents' utility bills, which is implemented by the CPUC.

California has experience with consumer rebates for efficient water heaters. Rebates of 30$ are currently available for products with EF ≥0.62. Several rebate structures are possible for SEGWHAI water heaters, including providing incentives of $10 per EF point above the baseline and basing incentives on the incremental consumer prices of SEGWHAI products. Each participating utility will make the final decision on incentive structures.

California utilities are enthusiastic about gas efficiency programs like SEGWHAI, in part because their profits are not based on the quantity of gas they sell. Indeed, they do not lose money when they encourage consumers to save energy. In some states, however, utility rate regulations may limit the adoption of SEGWHAI rebate programs. In setting the rate that a utility may charge per therm sold, public utilities commissions have historically made a forecast of utility sales, and set the rate such that the utility would just recover its fixed costs. However, the result of this type of regulation is that utilities have an incentive to sell more energy than the forecast, since this increases their profits. This gives utilities a strong disincentive to participate in programs that are intended to reduce consumer gas use. This disincentive has been eliminated in California, Oregon, and Maryland (U.S. EPA 2006), by modifying utility regulations such that revenues are *decoupled* from sales (Bachrach 2004). This is done by means of *true-ups*, through which the utility rate in the next period is adjusted to account for over- or under-collection of fixed costs in the current period. Decoupling programs in other states may be necessary for SEGWHAI to find widespread success on a national scale.

Consumer demand can also be created through tax credits. A federal $300 tax credit is currently available for water heaters with EF ≥0.80. This credit has had a significant impact on the market share of tankless water heaters, which are currently the only products with EFs high enough to be eligible. Residential water heater manufacturers have protested the fact that this program only benefits foreign companies, since all tankless water heaters are manufactured overseas. The current tax credit expires in 2007, but its extension and modification to include SEGWHAI products may be possible. Tax credits can also be directed at manufacturers (see Section 3.4.4).

Financing

Incentives may not cover the entire incremental price of SEGWHAI water heaters. Consumers unable or unwilling to pay the remaining incremental price may still purchase SEGWHAI products if financing programs are available. These programs are likely to be especially valuable to the large percentage of consumers that purchase water heaters on an "emergency" replacement basis and do not have time to prepare for the higher initial purchase price. Several types of financing are possible. Leasing programs give consumers the option of leasing a water heater from the utility rather than buying one. Some utilities already offer this service for conventional water heaters of various types.[37] Another possibility is an on-bill financing program, in which the consumer owns the water heater but gradually pays off the loan as part of the monthly utility bill. Both of these options allow consumers to spread the initial water heater purchase cost over several years. A third possibility, mentioned in the U.S. DOE Water Heating Roadmap (2005), is a government-backed loan program for high efficiency water heaters.

*ENERGY STAR**

When choosing a new water heater, consumers place a high value on familiarity and reliability. Most consumers would likely perceive high efficiency water heaters with unconventional design approaches as a riskier investment than conventional products. In addition, though consumers value energy efficiency, they may have trouble interpreting efficiency information or lack confidence in manufacturer claims about efficiency. Branding by the ENERGY STAR* program attempts to overcome these barriers.

Jointly administered by the U.S. EPA and the U.S. DOE, ENERGY STAR* certifies and labels high efficiency consumer products. When the program began in 1992, it was focused on a single product category—computers and monitors[38]—but it has since expanded to include more than 40 categories. More than 60% of American households recognize and understand the ENERGY STAR* label. About 25% of households knowingly purchased ENERGY STAR* products in 2005, and more than 60% of them report that the label was an influential factor in their purchasing decision (U.S. EPA/U.S. DOE 2005). Nearly 200 million ENERGY STAR* units are purchased each year.

Water heaters are one of the few major appliances that do not have an ENERGY STAR* listing. The U.S. DOE investigated the feasibility of establishing an ENERGY STAR* water heater program in 2003. However, they concluded that:

- The highest efficiency gas and electric storage products are not sufficiently more efficient than the minimum efficiency standard to be worthy of an ENERGY STAR* label

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[37]. For example, Utilities Kingston of Kingston, Ontario: http://www.utilitieskingston.com/heaters/. Private companies can also offer water heater rental services; for example, America's Water Heater Resource, headquartered in St. Louis, Missouri: http://www.awhr.com/home.asp.

[38]. The Green Lights Program, which promoted energy efficient lighting, preceded Energy Star by one year. Green Lights merged with Energy Star in 1995.

- The more advanced technologies do not meet other ENERGY STAR* criteria, such as cost-effectiveness, proven reliability, and availability through multiple manufacturers and distribution channels.

However, in 2007, the U.S. DOE will reexamine the feasibility of an ENERGY STAR* label for water heaters. This time, SEGWHAI is involved in the discussions. Proposed SEGWHAI products should overcome the previous barriers to ENERGY STAR* adoption. Overcoming the barriers is likely to happen as Tier 1 SEGWHAI products will be conventional products with efficiency improved enough to merit an ENERGY STAR* label, and Tier 2 products will be advanced technologies that are more cost-effective than current options. Water heater manufacturers consider ENERGY STAR* an important tool for creating consumer demand for SEGWHAI products. In the SEGWHAI manufacturer survey, respondents rated ENERGY STAR* as one of the two most important activities to accelerate the market introduction of high efficiency water heaters.[39]

The adoption of an ENERGY STAR* program that includes SEGWHAI water heaters is complicated by the fact that SEGWHAI products are not yet available on the market. However, though ENERGY STAR* specifications are not usually established before qualifying products are available, ENERGY STAR* staff has not precluded this possibility. In addition, ENERGY STAR* sometimes adopts two sets of specifications simultaneously; a “current” specification and a “future” specification. Though the latter is not required for an ENERGY STAR* label until a specified point in the future, manufacturers can choose to meet it early. This approach rewards currently available high efficiency products while encouraging manufacturers to pursue greater efficiency improvements in the future.

An additional challenge to the adoption of ENERGY STAR* specifications for water heaters is ENERGY STAR*’s commitment to fuel neutrality (Karney 2006). In new construction and major remodels, builders choose whether to install gas or electric water heaters[40]. This decision is made on the basis of purchase price and product characteristics, including (potentially) ENERGY STAR* certification. For this reason, ENERGY STAR* staff believes that fuel neutrality requires that certification be available for both gas and electric products. However, most water heaters are sold as replacement units rather than for new construction. In the replacement water heater market, the choice between gas and electricity has already been made, since the site is wired for electricity or plumbed with a gas line. It is therefore reasonable to believe that a gas water heater certification program could proceed on its own schedule, independent of electric water heaters, without violating ENERGY STAR*’s commitment to fuel neutrality.

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[39]. The other highly rated activity was customer rebates. See Section 3.3 Manufacturer Interests and Capabilities, for more information.

[40]. In California, few electric water heaters are installed because Title 24 regulations strongly discourage electric water heating.

Consumer Awareness

ENERGY STAR* labels will be effective in alerting consumers to the efficiency benefits of SEGWHAI water heaters. However, other methods will be necessary to ensure that consumers are aware of available rebates, tax credits, and/or financing programs for these products.

Consumer education and outreach needs should be pursued through the full range of media channels. The tankless water heater industry has successfully increased awareness of their product and its benefits through home improvement shows, websites, and magazine advertisements. Storage tank water heaters meeting SEGWHAI criteria will need a similar marketing push to generate consumer demand and interest. For example, a home improvement show could emphasize the fact that SEGWHAI-qualifying water heaters offer the performance consumers expect from conventional water heaters, but with reduced emissions; and the energy savings of tankless water heaters, but at lower installation costs.

Manufacturer and utility point-of-purchase displays in retailer locations [41] will also be useful for consumers who purchase their water heaters through this channel. It will be more difficult, however, to directly educate consumers who purchase water heaters through plumbers. In this case, it may be necessary to rely on the plumbers themselves to alert consumers of available incentives. Plumbers will be motivated to do this if they receive their own incentive for installing SEGWHAI products (Section 3.4.3 Wholesalers, Retailers, Builders).

3.4.3 Wholesalers, Retailers, Builders

Manufacturers sell water heaters to wholesalers and discount retailers. Wholesalers and discount retailers sell products to plumbers, who sell them to consumers. Big box stores also sell products to consumers directly. When a new home is built, the water heater to be installed is generally chosen by the builder. Therefore, even if SEGWHAI products are developed and consumer demand for them exists, wholesalers, discount retailers, plumbers, and home builders must also be motivated to procure, stock, sell, and install the products for them to be successful in the market.

Incentives

Ensuring that wholesalers, discount retailers, and plumbers are motivated to stock and sell SEGWHAI compliant products may require utility rebates directed at these market actors. Upstream incentive programs of this type have proven successful in the past. As noted above (see Section 3.3.4 Manufacturer Issues and Perspectives), a recent program in a PG&E service area offered an incentive of $10 to water heater wholesalers for each efficient unit (EF ≥0.61) stocked. Of this incentive, $3 was kept by the wholesalers and $7 passed through as a discount to plumbers. This program provided incentives for more than 35,000 efficient water heaters, with a TRC-effectiveness value of 4.35 (Robert Mowris & Associates 2004). As discussed above, an upstream incentive program may also increase consumer demand for SEGWHAI water heaters by encouraging plumbers to mention SEGWHAI products to their customers.

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[41]. Manufacturers may choose to provide point-of-purchase displays in order to increase consumer awareness of their SEGWHAI products. If they do not, SEGWHAI funding may be available to encourage manufacturers to develop displays.

Installer Training

If SEGWHAI compliant products involve any differences in installation procedure compared to conventional gas water heaters, it is important to provide training programs for contractors. This will not only ensure that they are able to successfully install SEGWHAI products, but also heighten their awareness of these products, and in doing so, they will be more likely to mention them to consumers who are selecting a new water heater. The U.S. DOE Water Heating Roadmap (2005) recommends that a centralized entity be formed to train and certify installers, as well as to publicize the products in trade magazines and at trade shows. In California, PG&E, SoCalGas, and SDG&E conduct extensive training programs in support of their energy efficiency programs. It would be relatively easy to expand these training programs to include classes for plumbers on installation of SEGWHAI products.

Title 24

When a new home is built in California, the water heater to be installed is chosen in part to ensure that the home meets the Energy Commission's Title 24 Building Energy Efficiency Standards. Installing a more efficient water heater allows the builder to invest less in the efficiency of other aspects of the building. For the purpose of Title 24, water heater efficiency is determined in such a way that storage water heaters are at an unfair disadvantage when compared to tankless water heaters.[42] However, a proposal is being considered that would correct this situation in the 2008 revision to Title 24, and it would increase builders' motivation to install SEGWHAI water heaters in new homes.

3.4.4 Manufacturers

For SEGWHAI to be successful, water heater manufacturers must have both the motivation and the ability to develop and market SEGWHAI water heaters.[43] Manufacturers appear to be well-equipped to develop SEGWHAI products, but will not do so unless they can see a market and a way to profit from them. Strategies to increase manufacturer motivation and ability are discussed in the following sections.

Motivation

Manufacturers currently have little motivation to develop high efficiency water heaters, primarily because they do not believe that there is sufficient consumer demand for these products. Therefore, the strategies discussed in Section 3.4.2 Consumers to create consumer demand will simultaneously increase manufacturer motivation. However, in order for manufacturers to invest in developing SEGWHAI products, they need assurance that programs

[42]. Storage water heaters are simulated in a manner than accounts for their load-dependent EF (LDEF). CEC PIER and PG&E Emerging Technology research has found that tankless water performance is overestimated by the EF test, and a proposed tankless degradation is being considered for the 2008 Title 24 Standards.

[43]. In *Seeing What's Next: Using the Theories of Innovation to Predict Industry Change*, the authors (Christensen et al. 2004) emphasize that motivation and ability are necessary in order for innovation to occur. They define motivation as "a pot of gold waiting for the winners"; in other words, manufacturer belief that their product development efforts will be profitable. Ability is defined as "the capability to obtain resources, craft them into a business model, and offer products and services to customers".

to create consumer demand will be in place for at least five years.[44] Unfortunately, funding for utility rebate programs in California is currently approved on a three-year cycle. Manufacturers are not likely to invest in the development of new products that may only be supported for three years.

A CPUC resolution guaranteeing longer-term support of water heaters that meet SEGWHAI criteria would give manufacturers the certainty needed to commit to developing SEGWHAI products.

While programs to create consumer demand for SEGWHAI products are effective means of motivating manufacturers to develop these products, other strategies can be directed at the manufacturers themselves. For example, the Energy Policy Act (EPact) of 2005 provides manufacturers' tax credits for certain appliances, including dishwashers and clothes washers. The program is tiered, with manufacturers of higher efficiency products being eligible for higher tax credits. Only products manufactured in the United States are eligible for these credits, since increased domestic employment is one of the goals of the program. A key advantage of this approach is that it is implemented at very low-cost as part of the taxes paid by the manufacturers. SEGWHAI is investigating the possibility of including water heaters in future manufacturer tax credit programs. This would increase manufacturer motivation to develop SEGWHAI products by increasing the profits that they can achieve by selling these products.

Ability

Evidence suggests that manufacturers have the ability to develop SEGWHAI products. Responses to the SEGWHAI manufacturer survey implied that manufacturers expect to be able to develop SEGWHAI products (Section 3.3 Manufacturer Interests and Capabilities). The water heating industry is well established, and the major manufacturers have decades of experience developing and marketing new products. To meet changing regulations in recent years, they have replaced their insulation blowing agent, incorporated FVIR design, and improved product efficiency. They are also in the process of developing products to meet SCAQMD's low-NO_X requirement. Manufacturers test all new products extensively to be sure that they meet rigorous safety and longevity standards.

However, though major manufacturers have the resources to develop SEGWHAI products, smaller manufacturers and independent innovators may not. To increase competition and ensure that the most cost-effective products are developed, it may be useful to allow minor manufacturers and independent innovators to participate in SEGWHAI. SEGWHAI will need to provide funding for prototype development (see Section 4.2 Prototype Competition Plan) for these players to have the opportunity to participate. An important requirement for the non-major manufacturers is a solid connection to a volume manufacturing entity to ensure that SEGWHAI products can meet price and production targets.

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[44]. According to the SEGWHAI manufacturer survey (Section 3.3 Manufacturer Interests and Capabilities).

Although the major manufacturers may have the ability to develop innovative products, outside support can still be effective. In April 2006, a major manufacturer introduced a condensing unit for the residential combined hydronic market that costs half as much as competing high capacity condensing water heaters. This unit was developed with funding from U.S. DOE. The authors believe that SEGWHAI's support for prototype development will lead to a similar success.

All manufacturers will also be invited to participate in SEGWHAI field and laboratory testing. This testing will probably be implemented through utility emerging technology programs. In California, PG&E is ready to begin side-by-side laboratory testing of a range of water heaters, and SoCalGas has expressed interest in pursuing field testing. This testing will enable utilities to evaluate potential SEGWHAI water heaters before providing incentives for them and will also assist manufacturers in assessing their own products.

Another potential barrier to the development of SEGWHAI products is the set of water heater safety, materials, and energy efficiency standards. Though these standards do not explicitly limit the ability of manufacturers to develop SEGWHAI water heaters, SEGWHAI products may incorporate technology or materials changes that standards do not currently accommodate. For example, certain types of flue dampers, check valves, gas valves, and burners may be disallowed under current standards. To improve the ability of all manufacturers to bring SEGWHAI products to market, it may be necessary to change standards to accommodate new technologies in ways that do not compromise consumer safety.

3.4.5 Lessons Learned from Past Efficiency Programs

The U.S. DOE evaluated three major U.S. energy efficiency technology procurement programs in 1999 to help program developers create better programs (Ledbetter et al. 1999). The programs evaluated were:

- SERP
- High Efficiency Clothes Washer Volume Purchase
- Sub-Compact Fluorescent Lamp Technology Procurement

A few key lessons learned, and their implications for SEGWHAI, are discussed below:

- The program development process should be buyer-driven. According to the authors, "too many government or utility-sponsored energy efficiency programs in the United States are driven by technology advocates, whose enthusiasm for a particular technology or design feature is given more weight in program design than the intended buyers of the target technology, resulting in programs that are less effective than they could be." SEGWHAI is making a concerted effort to avoid this pitfall. The SEGWHAI technical specifications do not require any particular technology; they are simply performance specifications, requiring a minimum efficiency level, a maximum gas input rate (to ensure ease of replacement), and a NO_X emissions standard (see Section 4.1 SEGWHAI Technical Specifications). In addition, as this report indicates, SEGWHAI has closely considered the needs and preferences of water heater consumers.
- Even though the program development process should be buyer driven, program developers should nonetheless interact extensively with potential suppliers of the

technology being sought. SEGWHAI has sought and received considerable input from the three major U.S. water heater manufacturers. Representatives of the three manufacturers have participated in the SEGWHAI Steering committee. All companies submitted responses to the SEGWHAI manufacturer survey and SEGWHAI staff members have engaged manufacturers in one-on-one discussions.

- It is very important to thoroughly understand the conventional delivery channels for the types of products or technologies that are the focus of a technology procurement project. SEGWHAI has researched the water heater distribution chain, and the results of this research are presented in Section 3.2 California's Small Gas Storage Water Heater Market. SEGWHAI has also carried out a survey of water heater installers, who are vital links in the distribution chain.
- The higher the retail cost of the target technology, the more expensive and difficult the technology procurement program will be. This is the reason for the proposed SEGWHAI incentive programs, including financing, rebates, and tax credits.
- It is easy to underestimate the size and importance of the promotional/educational part of technology procurement programs. Proposed ENERGY STAR* labeling and manufacturer displays in discount retailers will alert consumers to the efficiency benefits of SEGWHAI as well as to any available incentives. As discussed above, the situation is more difficult for consumers who purchase water heaters through plumbers. However, if plumbers receive incentives for installing SEGWHAI products, they will be motivated to notify consumers of incentives available to them. Training and education programs directed at plumbers will also make plumbers more likely to offer SEGWHAI products to consumers.
- Having institutions that are recognized for objectivity, consumer interest, or technical expertise involved in the development and implementation of technology procurement programs can contribute significantly to the success of such programs. For this reason, the SEGWHAI Steering committee includes representatives from the Energy Commission, the CPUC, the U.S. DOE, SCAQMD, LBNL, the ACEEE, Natural Resources Defense Council (NRDC), NRCan, GTI, GAMA, the American Gas Association (AGA), the New York State Energy Research and Development Authority (NYSERDA), gas utilities, and water heater manufacturers.

3.4.6 California State Energy Efficiency Policy Initiatives

CPUC Big, Bold Initiative for 2009 – 2011: High Efficiency Residential Gas Water Heater Program Recommendation

The CPUC released the "Notice of Prehearing Conference and Staff Proposal for Implementation of 2009–2011 Energy Efficiency Portfolio Development and Long Term Goals Update" (CPUC 2007) on February 16, 2007, which is the next step in the Rulemaking 06-04-010, established April 13, 2006. Section "2. Innovation" contained four suggested "Big, Bold" program concepts. The fourth of these Big, Bold concepts was:

- Achieve X% market penetration of SEGWHAI qualifying residential and small commercial retrofit/replacement gas water heaters by 2011, Y% by 2014, and incorporate into Title 20 (or Title 24) building standards by 2014.

SEGWHAI is proposing two EF efficiency tiers: 0.70 EF, non-condensing; and 0.82 EF, condensing.

Three Big, Bold scenarios are developed and briefly discussed in this summary. The best case scenario is projected to have the following characteristics based on the performance of all the units installed over the 14-year Big, Bold SEGWHAI program. These characteristics are:

- Annual therm savings of 1917 million are achieved in 2020.
- Avoided CO_2 emissions in 2020 are 11 million M/T/yr.
- Therm savings and avoided CO_2 emissions are achieved at 6% of the cost of the California Solar Initiative (CSI).
- Estimated budget is under $1 billion dollars for a 14-year program that can be cost-effectively administered by the PG&E, SoCalGas, and SDG&E under the auspices of the CPUC, enhanced by CEC Building Energy Efficiency Standards (Title 24) actions.

At the February 26th, 2007 SEGWHAI steering committee, project staff was directed to develop a concise summary of recommendations in response to the CPUC suggested initiative.

Recommended List of Actions

- CPUC establishes, in coordination with the Energy Commission, Legislature, and the Governor, a Super Efficient Residential Gas Water Heater Program to be conducted from 2007–2020 with a budget of $925 million funded by the ratepayers of California under the auspices of the CPUC.
- The Energy Commission modifies the 2008 Title 24 and Title 20 Standards to make EF 0.62 water heaters a prescriptive requirement.
- The Energy Commission modifies the 2011 Title 24 and Title Standards to upgrade from EF 0.62 to EF 0.70.
- California Investor Owned Gas Distribution Utilities (PG&E, SDG&E Company and SoCalGas Company) administer incentive programs with the goal of changing the installed population of residential gas water heaters to Tier 1 or higher efficiency by 2020. Natural gas savings would be credited to the gas utility's natural gas portfolio goals established by the CPUC.

- Manufacturers commit to supplying water heaters to California that cost-effectively achieves Tier 1 and Tier 2 EF levels while also meeting the NO_X requirements of California Air Quality Management Districts.

Big, Bold Residential Water Heating Scenarios

The three scenarios listed below show that by 2020, it is possible to achieve annual savings of up to 350 million therms while avoiding up to 2 million M/T of CO_2 emissions. The year 2020 is used as a benchmark to align the Big, Bold scenarios with the California GHG Policy as set forth in Assembly Bill 32, and signed by Governor Schwarzenegger on September 27, 2006.

In all three scenarios, incentive programs administered by PG&E, SDG&E, and SoCalGas achieve a TCR benefit ratio of 1.0 or better. Program costs include all incentives and a program administration budget of 10%.

The three scenarios described in Table 3-26 are:

- BB No Standards: Program with no changes to Title 24 Building Standards or Title 20 Appliance Standards to support higher efficiency water heaters. Incentives are given for all three product types with EF 0.62 and higher through 2020.
- BB Timeline, 2014 Standards: Program with Title 24 and Title 20 standards making Tier 1 EF 0.70 water heaters a prescriptive requirement in 2014. Tier 2 units are given incentives through 2020.
- BB Early Standards: Program with Title 24 and Title 20 standards making EF 0.62 water heaters a prescriptive requirement in 2008 and upgrading to Tier 1 EF 0.70 products in 2011. Incentives are provided for Tier 2 units through 2020.

Table 3-166. Big, Bold Water Heater program scenarios: 2020 annual impacts generated by installed SEGWHAI units during program years 2007-2020

	Scenario	Total Program Cost (Million)	Annual Savings from Installed Units (Millions of Therms/yr)	Program Cost per Therm Saved	Annual Million M/T CO_2 Avoided	Total Tier 1 & 2 Units Installed	X% Tier 1 & 2 installed by 2011	Y% Tier 1 & 2 installed by 2014
A	BB No Standards	$573.50	106	$5.38	0.62	1,916,500	1.2%	5.0%
B	BB Timeline, 2014 Standards	$833.30	265	$3.14	1.55	6,764,000	1.7%	10.5%
C	BB Early Standards	$894.70	353	$2.53	2.07	8,874,000	3.7%	31.7%

Figure 3-20 displays the first year savings generated by newly installed program water heaters under the three different scenarios. The value of the early standards scenario clearly shows the large savings achieved in the first five years of the "Big, Bold" initiative, which then continue to climb. With standards in place, savings continue even after the average 13-year useful life of water heaters.

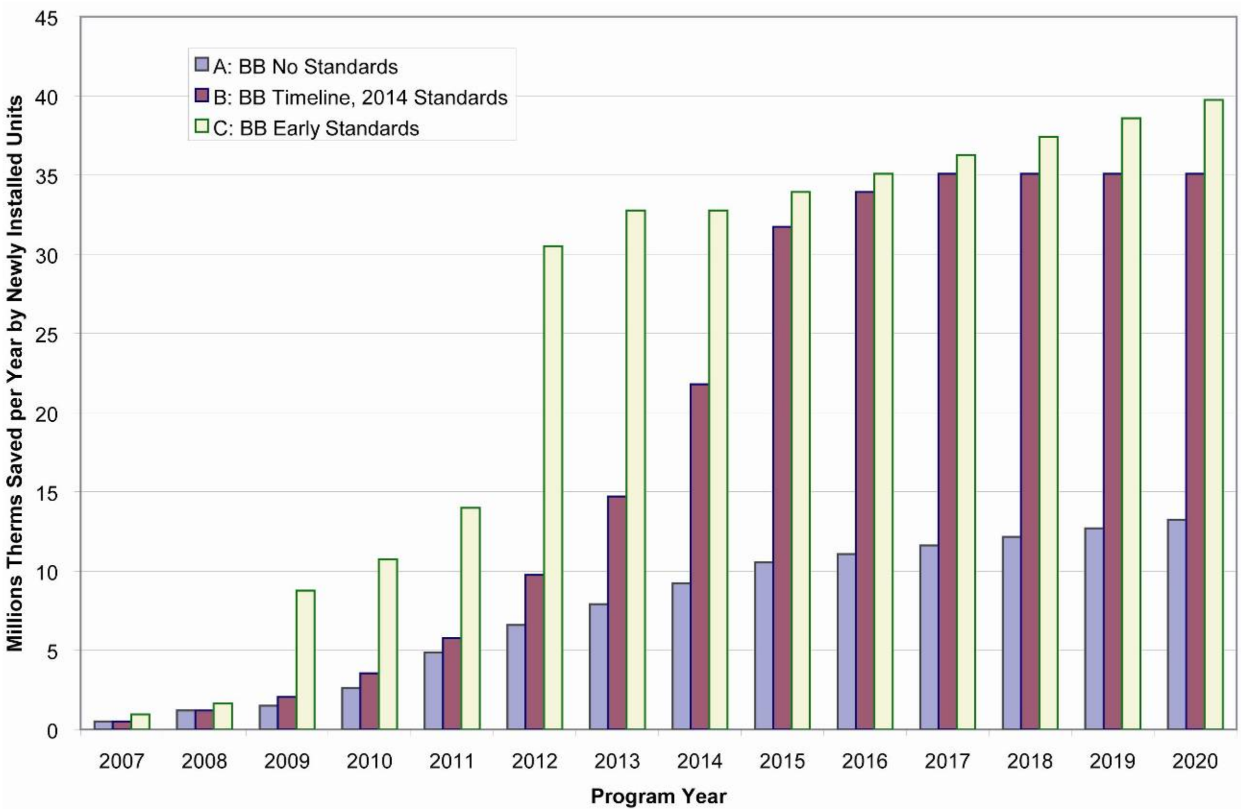

Figure 3-20. Big, Bold CPUC Water Heater program first year therm savings from newly installed units

CPUC Big & Bold Water Heater Program: Committed through 2020

Throughout the SEGWHAI process, water heater manufacturers have clearly stated that they can not make business plans for the introduction of the energy efficient water heaters in California without a long term commitment to fund incentives. The 10-year commitment made by the CSI sets the precedent for such action by the CPUC.

As part of Governor Arnold Schwarzenegger's Million Solar Roofs Program, California has set a goal to create 3,000 megawatts of new, solar-produced electricity by 2017, thereby moving the state toward a cleaner energy future and helping lower the cost of solar systems for consumers. The CPUC, through its CSI, provides over $2 billion in incentives over the next decade for existing residential homes and existing and new commercial, industrial, and agricultural properties. The Energy Commission manages a 10-year, $350 million program to encourage solar in new home construction through its New Solar Homes Partnership. The overall goal is to help build a self-sustaining photovoltaic, solar electricity market. The current program does not fund solar hot water systems.[45]

A budget of $2.167 billion established by Senate Bill (SB1) will be used to pay incentives and operate the Million Solar Roofs program. In the 2007–2008, California Legislative sessions AB

45. http://www.gosolarcalifornia.ca.gov/csi/index.html emphasis added

1470 has been introduced to establish a 10-year program to install 500,000 solar hot water systems. Currently, the most cost-effective solar water heaters cost about $3000, save about 80 therms/yr, and receive a 30% Federal Tax Credit. Reduction of GHG is the goal of the initiative, and the far right column of Table 3-27 demonstrates the annual cost of each ton of avoided CO_2, with the Solar Hot Water program being the least cost-effective. The photovoltaic program cuts the cost of avoided CO_2 emissions almost in half while the Big, Bold program reduces the cost to 20% of the Solar Hot Water program. To meet the GHG emissions goals set by AB 32—over 70 million tons annually—the State will need to implement all feasible programs including a Big, Bold Residential Water Heater program.

Table 3-177: Comparison of CSIs to best Big, Bold scenario

Program	Program Budget, $ Billion	Millions of Therms saved	Million M/T of CO_2 Avoided	$/M/T of CO_2 Avoided
CSI	2.167	Not Applicable	1.57	$1,379.69
California Solar Thermal 2007 - Solar Hot Water	0.500	40	0.23	$2,136.75
Big, Bold Water Heater Early Title 24 & 20 Standards	0.895	353	2.07	$433.11

Implementation of a Big, Bold Water Heater program could begin as early as 2007 and run through 2020 to achieve maximum cost-effective savings and GHG emissions reductions. Applying the precedent of CSI will allow all stakeholders to plan and implement an optimal scenario, thereby achieving the most savings at the lowest cost.

3.5 Technical Foundations and Pathways for Gas Water Heater Technology Improvements

3.5.1 Overview

Automatic water heaters became common home appliances in the United States in the first half of the 20th century. In the early years, more than 150 manufacturers sold a wide variety of water heater types, including storage and tankless products powered by a range of fuels. As the market matured, competition and consolidation led to the ascendance of three manufacturers, all of whom focus on storage water heaters fueled by gas or electricity. Today, the typical residential gas water heater is a 40- to 50-gallon glass-lined steel tank with a center flue design, standing pilot, and a number of safety features to prevent explosion and fires. Baseline efficiency new residential gas water heaters now use an average of 185 therms of natural gas/yr for residential water heating (Section 3.1.4 E3 Inputs).

The performance evolution of the conventional gas storage water heater over the past 20 years has been characterized by incremental efficiency improvements. Combustion efficiencies and tank insulation levels have increased somewhat, most significantly with the latest NAECA revisions. Higher efficiency condensing products are available, but these units are costly and geared toward the combined hydronic market and commercial applications, not the mainstream residential “domestic hot water only” market. SEGWHAI hopes to act as a catalyst for the development of a high efficiency, mass market product that can be easily installed in the field with minimum incremental installation labor.

Prior water heater development projects and an analytical spreadsheet model using the WHAM equations were used as a basis for assessing the expected performance impacts of reducing standby losses, eliminating the center flue design, and improving combustion efficiencies (Lutz et al. 1998). Results suggest that EFs exceeding 0.70 are achievable for non-condensing storage water heaters, and EFs exceeding 0.82 are achievable for condensing units. To be competitive in the market, high efficiency water heaters should offer homeowners favorable economics and performance at least comparable to conventional products. Consumers need to understand and value the associated energy savings in order to accept the higher cost of efficient products.

3.5.2 History of Water Heating

Water heaters did not become common in American homes until the first half of the 20th century. At the turn of the 20th century, running hot water was still regarded as a luxury (Ruud Company used the slogan “Luxury Unlimited”), and early water heaters were often extremely ornate and today are examples of industrial art (Figure 3-21).

Figure 3-21. Gas tank heater, c.1908, Ruud Manufacturing Company, Pittsburgh, PA
Photo Credit: Ryan Hammond

Whereas today three manufacturers produce almost all of the residential water heaters sold in the United States (see Section 3.3 Manufacturer Interest and Capabilities), in the early 20th century there were more than 150 manufacturers, and a much greater variety of products (Weingarten 1995). Wood, coal, kerosene, gasoline, a variety of gases, electricity, and solar power have all been used to heat water. Tankless water heating technology was developed in the 1890s, and both storage and tankless water heaters were common in the early 20th century. Storage water heaters eventually prevailed over tankless products in the United States, possibly as a result of the increased popularity of showers over baths. Controlling water temperature precisely is more important for showers than for baths, and in the early years such control was difficult to achieve with tankless water heaters. Solar water heaters also began gaining popularity around the turn of the century, but eventually were unable to compete with the low-cost and convenience of natural gas that was widely available by the 1950s.
Early 20th century water heaters tanks were generally made of galvanized steel, copper, bronze, or MONEL®. Galvanized steel is low in cost but does not last very long, while MONEL (an alloy of iron, copper and nickel) costs the most and has an extremely long lifetime. However, with the innovation of low-cost ceramic or glass tank lining to reduce the likelihood of corrosion, manufacturers stopped using the more expensive metals and focused primarily on steel.

Early water heaters lacked the safety features of modern products. For example, automatic shut-off mechanisms did not exist, so if a pilot light blew out, the user would need to ventilate the room before reigniting it. In early tankless products, if the water was not flowing before the burner was ignited, the product would be damaged and potentially destroyed due to overheating. Electric point-of-use water heaters brought bare heating coils in direct contact with cold tap water. Because they were ungrounded, incorrect use of these products could result in electrocution. From today's vantage point, it is hard to believe they were used at all. To compensate for the lack of automatic safety features, manufacturers sometimes designed physical safety features into their water heaters, such as levers that could only be operated in a particular order. This increased safety by minimizing the potential for user misuse (Weingarten 2005).

3.5.3 The Modern Gas Water Heater

The common gas storage water heater shown in Figure 3-22 has a center flue design, a glass-lined steel tank, and an atmospheric burner located at the base of the tank (U.S. DOE 2000). The tank is surrounded by foam insulation, which is covered with a sheet metal jacket. The level of tank insulation has improved over the years, and with the 2004 NAECA increase in the minimum required EF, most units have an average R-value (measure of thermal resistance in heat transfer problems) exceeding R-10.

Typical tank volumes are 40- or 50-gallons, with 50-gallon tanks increasingly common in new homes as both the number of hot water fixtures and homeowner expectations increase. Gas is combusted in a burner at the bottom of the unit, typically at a rate of about 40,000 Btuh. The center flue design typically includes a continually burning pilot light that uses gas at a rate of roughly 400–500 Btuh, consuming about 40 therms of gas/yr (U.S. DOE 2000). Combustion products rise through a flue in the center of the tank. To control corrosion, a sacrificial anode rod is suspended inside the tank. A dip tube, also suspended in the tank, delivers cold water to the bottom of the tank to be heated, while hot water is pulled from the top of the tank. A thermopile heated by the pilot light generates electricity that is used by the gas valve which opens and closes to maintain the temperature set point. The gas valve is normally closed so that if the pilot goes out the gas valve remains closed. A drain valve at the bottom of the unit is used to empty the tank when necessary for maintenance (Weingarten 1992).

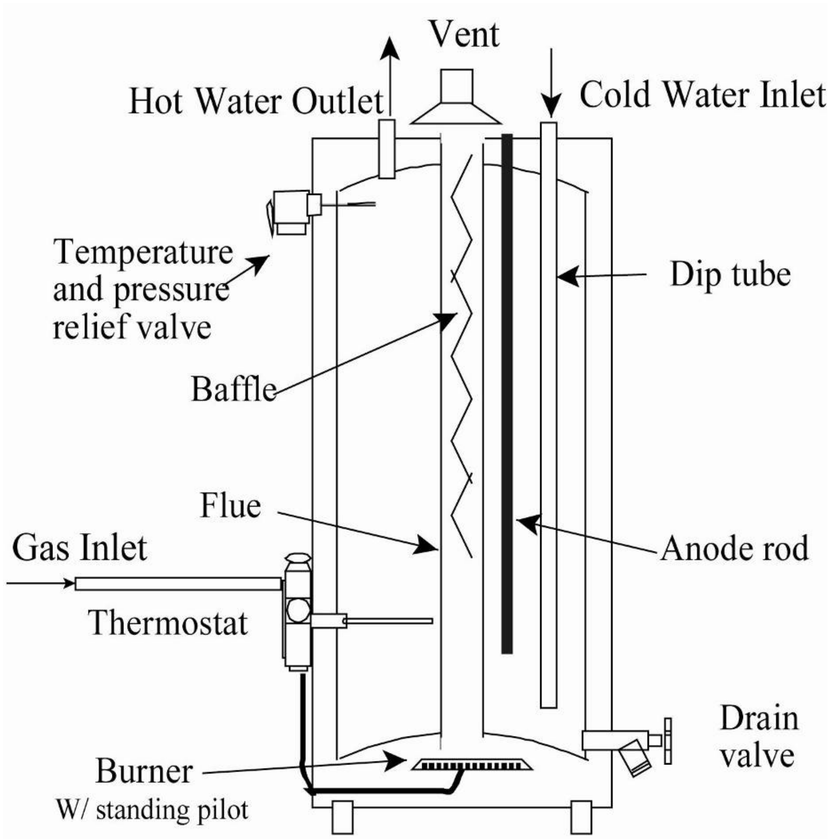

Figure 3-22. Standard gas storage water heater

Safety Features

Modern water heaters have multiple safety features. To prevent overheating and the possibility of explosion, the high-limit safety switch, also called the emergency cut-off (ECO), shuts down the water heater if the water temperature reaches 88°C (190°F). If the ECO fails, the temperature and pressure relief (TPR) valve will open when the water temperature reaches 99°C (210°F). This prevents boiling and potential explosion by releasing hot water and allowing cold water into the tank. The TPR valve also opens if the water pressure reaches 150 pounds per square inch of pressure.

Other safety features include dual wall flue piping, flexible connectors for water and gas lines, and, in earthquake-prone regions, earthquake straps to secure the water heater to the wall preventing overturning. Water heaters installed in garages are also required to have protective bollards to avoid damage from cars, and be installed on 18-inch platforms to protect against flammable vapors.

Recent technological efforts of the major water heater manufacturers have been in the areas of combustion safety and, more recently, the control of combustion emissions. Beginning in 2003, manufacturers have been required to include FVIR design features in new water heaters to eliminate the potential of igniting combustible vapors that may be in the proximity of the gas burner. Each manufacturer has its own approach to implementing FVIR, but all incorporate the components shown in Figure 3-23.

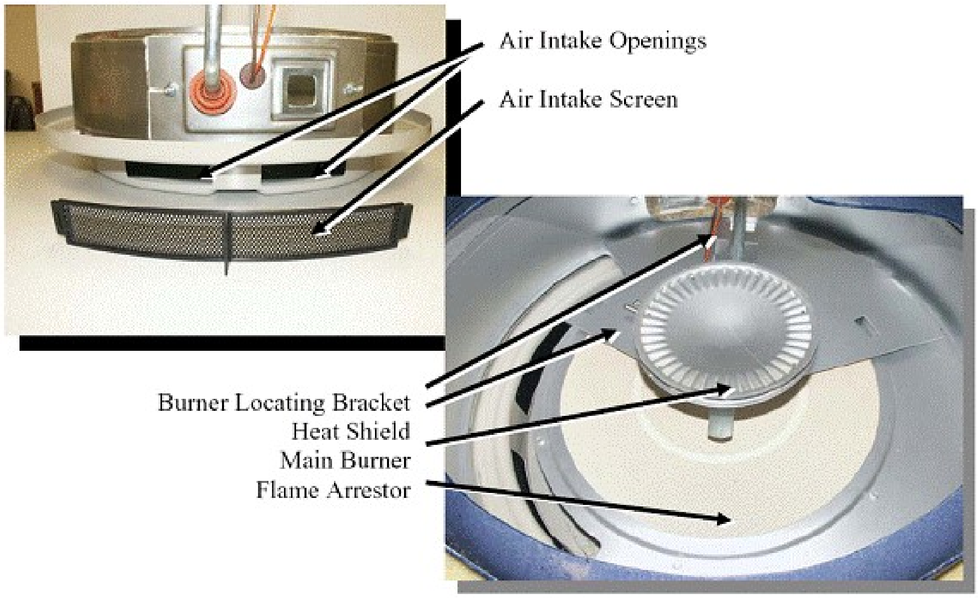

Figure 3-23. FVIR components
Photo Credit: State Water Heaters

The air pathway to the burner is modified to first screen out dust, lint, and other debris where it can be cleaned off when airflow becomes inhibited to the extent that combustion is hindered. Some designs extend the air pathway by having the air intake on the side of the heater in an effort to reduce the intake of lint and other debris. Next, a fine mesh screen made of specialized material works as a flame arrestor, stopping flames from leaving the combustion chamber. A sensor is located in the combustion chamber that senses an explosion and shuts off the gas valve. A push button piezo electric sparker is provided to ignite the standing pilot light. The sparker is needed because the FVIR water heater has a sealed combustion chamber with a gasketed access door to the burner and pilot. The push button igniter makes the pilot easy to light, since it is the same type of sparker used in gas outdoor grills.

Water heater manufacturers are currently focused on meeting SCAQMD requirements addressing NO_X emissions from gas storage water heaters of ≤50 gallons. The District's Rule 1121 requirement of 10 ng/J of heat output will be met in late 2007 by using radiant style burners, which will considerably reduce NO_X emissions relative to currently available units. Manufacturers are still working to optimize burner design and deal with issues related to clogging of the burner with LDO contained in the combustion air. As with FVIR, super low NO_X burners will need some additional maintenance to keep them functioning properly.

Other Districts in California, Texas and the Northeastern United States are in the process of considering and potentially adopting rules similar to Rule 1121. It is likely that more than 55% of the U.S. population will eventually live in regions that have NO_X requirements as stringent as SCAQMD (see Section 3.0 Energy and Environmental Benefits). Manufacturers predict that an atmospheric burner with passive flue gas venting meeting NO_X and FVIR standards will be significantly more expensive than baseline water heaters. Starting with these more expensive products as the baseline, the incremental costs of SEGWHAI water heaters may be reduced, making SEGWHAI products more cost-effective than they would otherwise be. An example of this phenomenon is being encountered in some installations where the cost of the vertical flue for a minimum efficiency water heater is so much more than a horizontal side wall plastic flue for a forced draft water heater that the total installed cost to the consumer is nearly the same for the more efficient forced draft unit.

Energy Efficiency

Gas water heater efficiency has improved significantly over the past few decades to meet the initial 1990 NAECA standards and the revised 2004 standards. In the 1980s, most manufacturers began replacing fiberglass insulation with more effective (and more economical) blown foam insulation, reducing jacket losses. Stack losses during burner operation have been reduced by improvements to the flue baffle, which is a twisted strip of metal that increases the turbulence of the combustion gases as they pass from the burner to the exhaust flue. In addition, though most water heaters use a standing pilot, some new models reduce stack losses by means of electronic ignition, in which the pilot is ignited only when it is needed. Electronic ignition allows use of a flue damper or draft inducer to close the flue when the burner is not firing, reducing convective losses from the flue. Finally, according to the 2006 GAMA directory, many new water heaters include heat traps, which increase efficiency by preventing heated water from thermo siphoning (hot water rising and cooler water falling) in the inlet/outlet plumbing when hot water is not being drawn. Heat traps can increase water heater EF by about 0.01 (Paul et al. 2000).

U.S. DOE Water Heater Framework Workshop

The U.S. DOE conducted a framework workshop on January 16, 2007 for the purpose of obtaining stakeholder input on the next round of water heater standards. Current optimistic schedule estimates would have the new standards adopted by March 2010, with an effective implementation date of March 2013. The Advance Notice of Propose Rulemaking (ANOPR) is scheduled for release in October 2008. U.S. DOE requested at the framework workshop that any relevant data be sent as soon as possible, but no later than June 2007.

3.5.4 Performance Characteristics of Gas Storage Water Heaters

The EF of a water heater can be improved by increasing the recovery efficiency (RE), decreasing the standby heat loss ("UA"), or both. RE is a measure of combustion efficiency, or how effectively the unit converts gas input energy into thermal energy stored in the hot water as the water is heated. The standby heat loss factor is a measure of how effectively heated water is kept hot in the tank. Inefficiencies associated with the center flue design and standing pilot degrade overall water heater efficiency, explaining the significant difference between the RE (typically 76–78%) and the EF (typically around 0.60, or 60%).[46] For standard atmospherically vented water heaters, the RE should not be much above 80%, since above this level exhaust flue gas temperatures are cooler, increasing the risk of water vapor in the combustion products in the vent pipe, leading to corrosion. In condensing water heaters, the combustion products are intentionally cooled below the dew point to recover available latent heat. In condensing systems, REs can exceed 90%, and due to the low temperature, low-cost plastic piping can be used for the vent system. Condensate is collected and piped away for code compliant disposal.

[46]. Tankless gas water heaters (without continuous gas pilots) have essentially zero standby loss, resulting in EF within a few percent of their rated RE.

Understanding the energy flows in a gas storage water heater is the first step toward identifying potential improvement opportunities. Figure 3-24 displays results generated by the TANK water heater simulation model for a typical 40-gallon gas water heater that meets the current NAECA efficiency standards, tested according to the U.S. DOE EF test procedures (hot water recovery load of 64.3 gallons per day) (Biermayer and Lutz 2006). The TANK model, which was developed by Battelle for GRI, projects that 61% of the energy input to the water heater leaves the tank in the form of hot water. Another third of the input energy is lost up the center flue, with slightly more than half of this stack loss occurring during the 22.7 hours per day that the tank is in standby mode. The remaining 7% of the input energy is lost through the water heater jacket and fittings. As the hot water recovery load varies from the 64.3 gallon/day level, the amount of energy lost during standby (jacket/fitting losses and stack standby losses) varies accordingly.

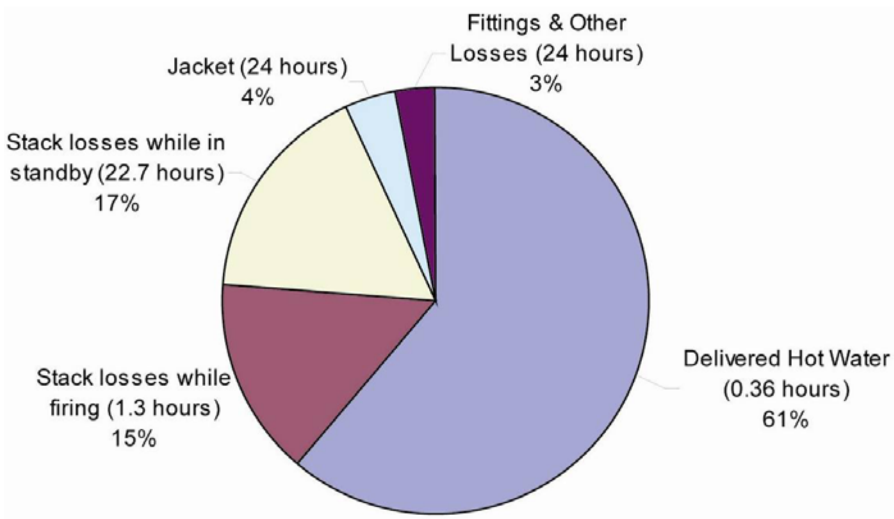

Figure 3-14 TANK projected energy flows for a 40-gallon water heater using EF test protocols

At higher hot water loads, the percentage of input energy delivered as hot water increases, and at lower loads, it decreases as standby losses become a greater percentage of the total energy consumed. Prior monitoring completed under U.S. DOE's Building America program at an occupied two-person household with a 50-gallon gas storage water heater (EF ~ 0.55) demonstrates the impact of daily hot water usage on gas storage water heater efficiency. Figure 3-25lots monitoring data from the project showing daily efficiency (defined as hot water energy leaving the water heater divided by natural gas energy consumption) as a function of hot water load for this site (Davis Energy Group 2003). The homeowners at the site used much less than the 64.3 gallons per day upon which the EF rating is based, thus requiring extrapolation of the data for values above 40 gallons per day. Efficiency drops as time in standby mode increases, with the extreme case being zero efficiency (i.e. zero useful heat output) when no hot water is drawn from the tank.[47]

Although the data is not intended to represent new water heater performance, it does clearly show gas storage water heater performance trends as a function of load (gallons of hot water

[47]. While tankless water heaters address the standby problem, there are other efficiency issues impacting tankless efficiency.

used per day). Two projected performance lines are drawn to show how SEGWHAI's Tier 1 and Tier 2 units might perform. Though real performance is unknown without laboratory testing, principal improvements can be predicted. At very low daily hot water demands, all storage water heaters will consume energy to cover the standby losses from stored hot water. Improved insulation (to minimize standby losses) and the absence of an open central flue and a standing pilot will give SEGWHAI units increased efficiencies, and with higher daily hot water use, the EF test efficiencies can be reached. The shape of the curves between the end points will follow a standard storage water heater, but will have improved performance at lower demands from the lack of an open central flue, no standing pilot, and better heat exchanger performance.

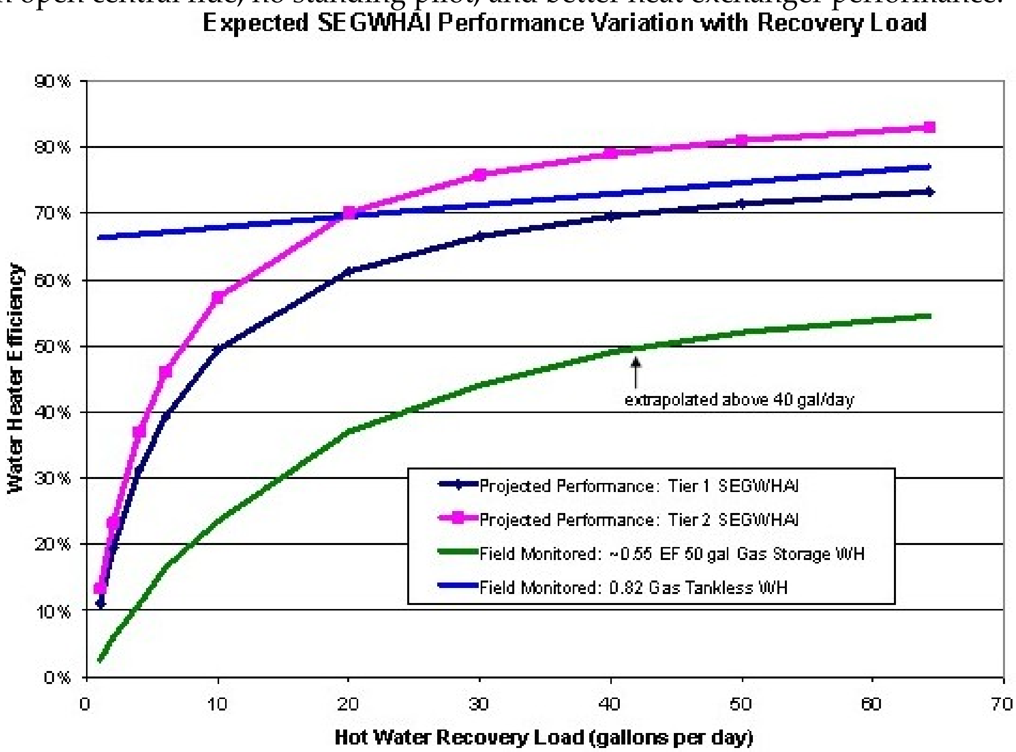

Figure 3-25 Monitored gas storage and tankless water heater efficiency compared to projected SEGWHAI performance

3.5.5 Water Heater Performance Baseline

Water heating energy use varies widely based on number of occupants per household and the manner in which they consume hot water. The concept of a *Load Dependent* EF shown in Figure 3-25 is being expanded to look at the impact of the number and types of hot water draws. CPUC water and energy efficiency programs are reducing the use of water and energy in homes. However, long, steady, and high volume hot water draws will continue to characterize showers and baths. Higher efficiency dishwashers and clothes washers use much less water, and can be characterized as medium volume draws. Many dishwashers have internal booster heaters and do not require 140 degree water to operate properly. In fact, some dishwashers are plumbed to the cold water supply and heat all of the water they use. The small, short-term draws at faucets vary widely between homes.

Research directed at developing a typology of home hot water use draws is currently underway. A computer simulation needs to be developed to estimate energy and water use based on the unique aspects of a home and the patterns and use characteristics of the homeowners and the water heater. It is probable that the existing EF test procedure needs to be revised to generate data needed for the computer simulation. But until this occurs, SEGWHAI will be based on the current EF test procedure, since it is the only legal efficiency metric for water heater labels and marketing. Analysis described in Section 3.1.4 E3 Inputs suggests that a reasonable figure for the baseline energy use of a 40- to 50-gallon storage gas water heater in California is 185 therms/yr. This is the baseline against which SEGWHAI energy efficiency improvements will be measured.

3.5.6 Characteristics of Efficient Storage Water Heaters

The data in Figure 3-24 strongly suggest several key performance improvement options for gas storage water heaters. TANK modeling suggests that 17% of the water heater's energy input can be attributed to the center flue design, with the absence of flue dampers. This percentage is certainly higher for households where ot water recovery loads are less than the 64.3 gallons per day assumed in the EF test. Another key improvement option lies in improving the RE from the current typical level of ~76% ("delivered hot water" and "stack losses while firing" in Figure 3-25 to the levels associated with condensing operation (over 90%).

A WHAM-based Excel spreadsheet developed by Jim Lutz of LBNL was used to evaluate how changes in performance parameters are projected to affect the overall EF (Lutz et al. 1998, 1999). Figure 3-26 plots the expected performance impact of reducing the tank UA of a 40-gallon, 0.59 EF water heater by half. This could be accomplished by various means, including higher tank R-value (a measure of thermal resistance in heat transfer problems), reduced fitting losses, heat traps, reduced center flue standby effects,[48] or reduced tank surface area per unit volume.[49] The lower line is for 76% RE, and the higher line is for 82% RE, representing the range of RE values for a non-condensing water heater.[50] Performance projections suggest that for every 10% UA reduction, the EF would increase by about 0.015. Forced draft, "power vent" water heaters have blowers that are only on when the unit's burner is firing. This greatly reduces the center flue losses, allowing some of these units to reach EFs as high as 0.67. The high non-condensing RE of this unit (82%) has the potential of condensing the flue gases, but this is not a problem because the vent is made of plastic.[51] Figure 3-26 demonstrates that if the standby losses are reduced to 50% of "normal", the simulation suggests that an EF of 0.71 could be achieved. The dashed horizontal line plots the EF 0.67 point that a GAMA listed water heater achieves. An RE of 82% is listed, which implies that the Storage Tank UA has been reduced to about 73% of the nominal.

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[48]. One option could be a flue damper system.

[49]. The current cylindrical tank design is not the most efficient in terms of volume per unit area. Although a spherical tank represents the optimal solution from a heat loss perspective, it is not a realistic option. Other alternatives that may be considered include phase change materials that could increase the energy density of the tank, allowing for a reduction in surface area and therefore standby loss.

[50]. RE values can range from 71%–85%, but are typically in the 76-82% range.

[51]. This is possible because excess ambient air is introduced to cool the flue gases enough to accommodate the use of plastic.

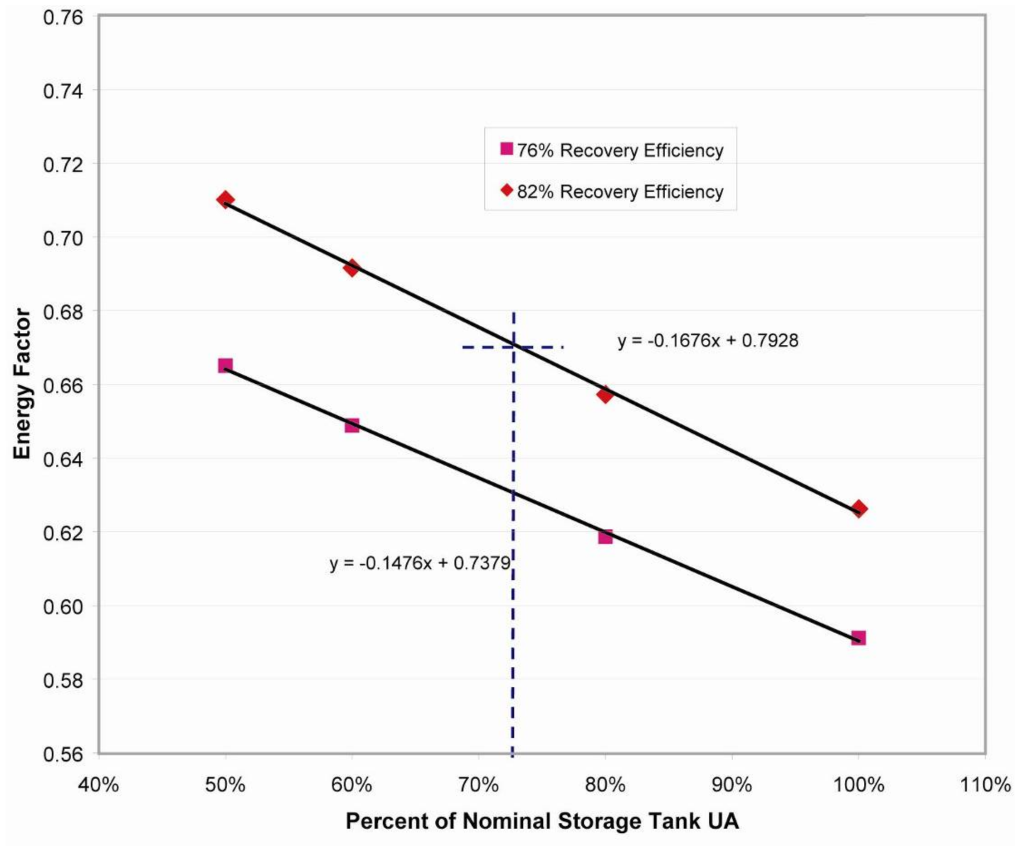

Figure 3-36. Impact of reduced standby loss on water heater EF

Figure 3-27 plots the performance impact of increasing the water heater RE from the typical 76% baseline level to condensing levels at about 90%. Relationships are shown both for standard center flue designs with gas pilots and also for designs with spark ignition, and either a side arm heater (which combines an electric tank with an external burner) or an effective flue damper, both of which would significantly reduce standby energy losses. A water heater with an RE of 76% and a center flue design is projected to have an EF of 0.59 with the nominal standby loss. Eliminating the center flue design or implementing an effective flue damper system is projected to increase the EF to approximately 0.70, by significantly reducing the off-cycle losses. As RE increases, non-center flue EF increases at a faster rate (0.0083 vs. 0.0056 per 1% increase in RE). If a condensing combustion efficiency of 90% could be achieved, a resulting EF of ~0.82 is projected at a nominal standby loss.

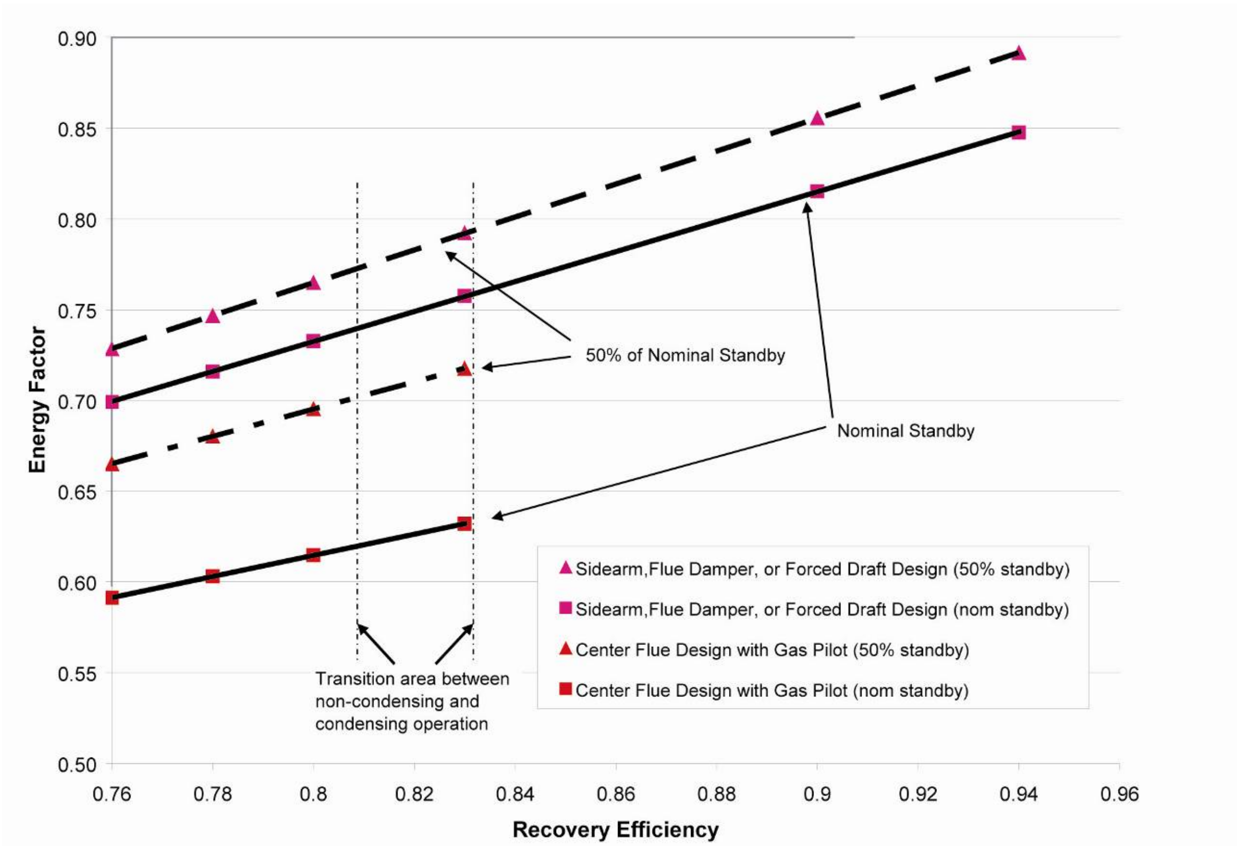

Figure 3-47. Impact of RE on water heater EF

3.5.7 Advanced Water Heater Development Case Studies

Three prior advanced storage water heater development efforts are described here to provide examples of potential directions for a R&D effort based on SEGWHAI criteria.

TIAX Development Effort

Arthur D. Little (now TIAX) completed a report for the GRI, U.S. DOE, and American Water Heater Co. in 2004, documenting the design, prototyping, and testing of an advanced storage water heater. Although, at 58,500 Btuh, this unit had a larger burner capacity than anticipated SEGWHAI products, it integrates features that offer significant potential for SEGWHAI. The unit produced by A.O. Smith as the Vertex has a 50-gallon tank, with a 76,000 Btuh burner providing condensing water heating performance with a 90% thermal efficiency, powered combustion air venting, and hot surface electronic ignition. Since the unit exceeds the 75,000 Btuh threshold, it is not tested and listed according to the EF test procedures, and it does not have to meet FVIR standards or the SCAQMD ULN standard. Data published in the GAMA Commercial Gas Water Directory suggest that if it were tested, the unit would probably achieve an EF in the range of 0.80–0.85. [52]

52. WHAM calculation using a thermal efficiency (TE) of 90%, standby loss of 364 Btuh, and volume of 50 gallons. TE is about 2-3% higher than RE, since it does not include the effect of standby losses.

Figure 3-58. Prototype heat exchanger design
Photo Credit: A.D. Little

The alternative heat exchanger design shown in Figure 3-28 provides enhanced heat transfer between water and combustion gases. The original A.D. Little prototype used a stainless steel heat exchanger that A.O. Smith has replaced with a steel heat exchanger that is glass-coated on both the inside and outside. A schematic of A.O. Smith's Vertex unit is shown in Figure 3-29. Contractor pricing for the Vertex is reported to be approximately $1,500, which is about half the price of other condensing storage water heaters. Strong sales will work to keep prices high until production capacity is increased to meet demand and encourages competition as other products enter the market.

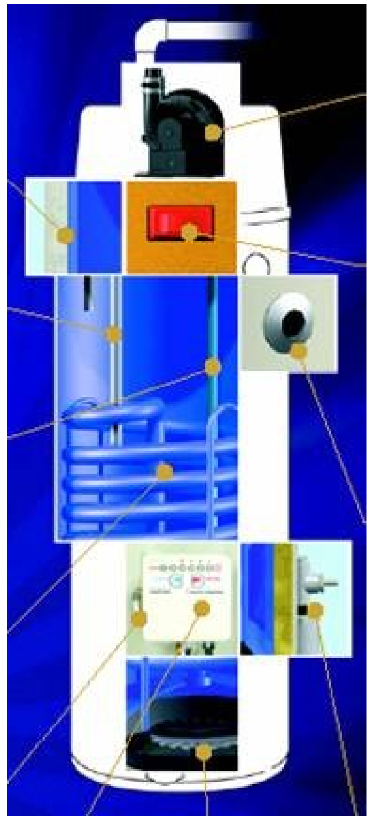

Figure 3-69. Vertex schematic
Photo Credit: A.O. Smith

The current Vertex design provides much more hot water than is needed for typical residential water heating applications. Based on market research during the Vertex development process, A.O. Smith determined that the optimal applications for the unit are the residential combined hydronic or small commercial markets.

Features included in the Vertex that could be incorporated in SEGWHAI designs include the advanced heat exchanger, improved gas control system, power vent system, and the advanced igniter system. Reducing the size of the tank, heat exchanger, and burner to a level consistent with residential hot water-only loads would reduce product costs somewhat[53] and increase the potential market size, increasing production economies of scale. An EF rating would be required for this new down-sized version of Vertex, allowing the consumer to make direct comparisons to other water heaters. At an EF of 0.80 or above, this new unit would be eligible for the $300 federal tax credit.

External Combustion Path Design

A 1983 American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Transactions paper entitled, "Development and Testing of an Improved High Efficiency Water Heater," reports on U.S. DOE-sponsored work carried out by the Oak Ridge National Laboratory and a private company (Advanced Mechanical Technology, Inc.) (Vasilakis et al. 1983). In this project, the goal was to develop a low-cost storage water heater in the non-

53. However, many of the costs associated with the Vertex would not scale with tank size.

condensing range with a target EF of 0.66. The design concept revolved around eliminating the center flue in an attempt to reduce the standby losses inherent in that design approach. The basic configuration of the residential scale 40-gallon unit (40,000 Btuh input) is shown in Figure 3-30. The burner is located under the storage tank and is surrounded by the heat exchanger. Water is heated by natural circulation. The storage tank is made of non-corroding polyethylene surrounded by insulation, with an exterior steel skin to provide structure. The use of polyethylene is intended to extend service life, generating life cycle benefits compared to traditional glass-lined tanks.

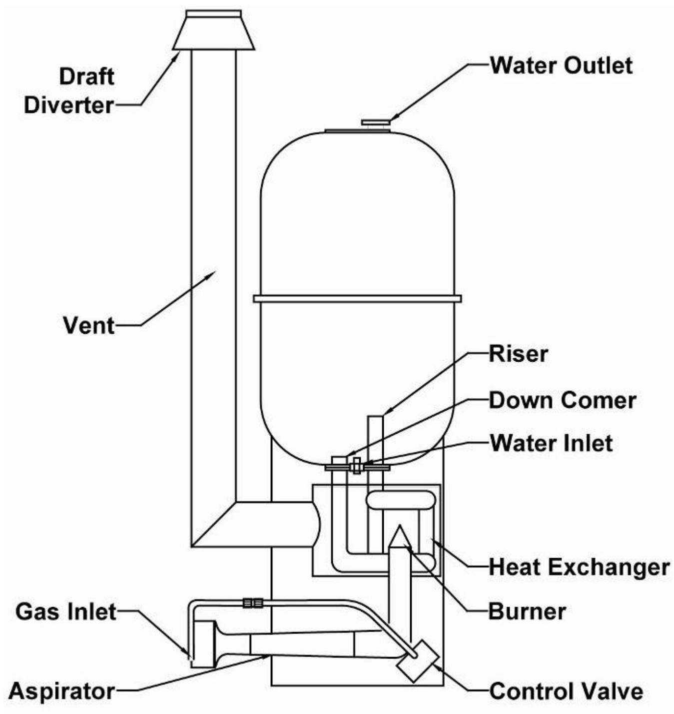

Figure 3-30. Schematic of external combustion design

Project results indicate that the prototype unit could achieve a RE of 80.6%, while maintaining a stack temperature high enough to avoid condensation and provide adequate draft. Reducing the number of tank penetrations and increasing insulation thickness resulted in a > 50% reduction in standby loss. This unit resulted in a test EF of 0.625. Additional tank insulation and elimination of the standing pilot with an intermittent ignition device was projected to increase the system EF to 0.71. Performance in this EF range is consistent with what one might expect from a well-designed, low standby, non-condensing design. Additional work is needed to ensure that this product would be small enough to fit in the typical two by two by seven ft water heater closet space.

Another approach would be to use a small capacity tankless water heater mounted as a side arm heater to the storage tank.[54] A fixed capacity tankless unit would eliminate cost associated

[54]. Examples of small capacity tankless units are the Paloma Legacy (http://www.palomatankless.com/products/ph6/legacy_ph6.html) and the Bosch AquaStar (http://www.tanklesswaterheatersdirect.com/shop/tanklesswaterheaters/manuals/38B_manual.pdf). Burner capacities are 43.8 kBtuh (fixed) for the Paloma unit and 20-40 kBtuh (variable) for the Bosch unit.

with controls and modulating gas valves. To keep the product small enough to fit in the standard water heater closet, water would probably need to be pumped out of the bottom of the tank, through the tankless water heater, and back into the top of the tank. An electronic ignition would be needed to bring the EF up to SEGWHAI Tier 1.

Two-Phase Thermosiphon Water Heater

A 1983 patent (U.S. patent number 4,393,663) describes the design of a water heater that uses a natural gas fueled heat source to evaporate a working fluid in the external burner assembly and then condense the fluid in the storage tank. This design, schematically shown in Figure 3-31, isolates the combustion components from the storage tank, effectively increasing system performance during the off-cycle as the restriction prevents flow back to the water heater. As the liquid-vapor mix is heated in the evaporator, the boiling vapor provides the pumping mechanism to drive the working fluid to the condenser. This simple thermosiphon design eliminates the need for a pump that would require energy to operate and maintenance over time. Performance claims suggest an EF in the range of 0.77–0.78 can be achieved at a reasonable incremental cost. It may be possible to configure the heat exchanger to come in the bottom of a tank similar to the one used in the 1983 prototype discussed above. This could make manufacturing easier and result in a lower-cost unit. A possible advantage of this system is that the sealed heat exchanger may prolong the life of the system by avoiding the buildup of hard water deposits that can block the small piping of tankless water heaters and coat the bottoms of standard storage water heaters.

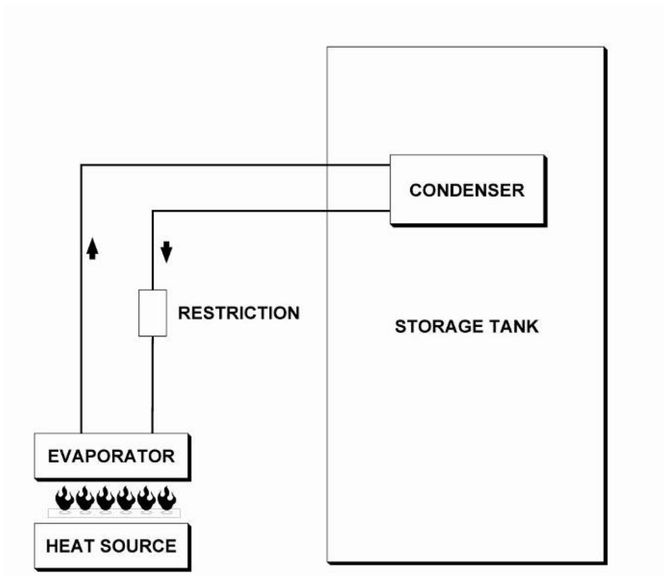

Figure 3-31. Schematic of two-phase thermosiphon design

3.5.8 Assessment of Potential Water Heater Improvement Options

Water heater manufacturers employ product development engineering teams that work to improve existing water heaters and develop new products. These teams take into account a wide variety of water heater design issues. However, other stakeholders in the SEGWHAI process may not know all the factors that must be considered as a water heater is designed, engineered, produced, and improved. The purpose of this section is to give all stakeholders a preliminary understanding of these issues.

Performance Issues

A wide range of issues must be taken into account in the design of SEGWHAI-compliant products. The most important of these are listed below:

- Technical Feasibility
    - Has the proposed measure (or package of measures) been successfully demonstrated in other applications?
    - Will the proposed configuration provide consistent performance over time?
- Manufacturability
    - Is the proposed design conducive to a mass production environment where economies of scale can be used to reduce manufacturing costs?
- Cost-Effectiveness and Market Acceptance
    - Can the proposed system be installed at a price level in line with the expected performance benefits?
- Ease of Installation
    - Is the proposed unit configuration compatible with a majority of existing residential water heater installation sites and is the installation process comparable to that for conventional water heaters?
- Comparable Hot Water Delivery Performance
    - Will the homeowner realize comparable and consistent performance (supply water temperature, first hour rating, hot water waiting time, maximum hot water flow rate, etc.) over the lifetime of the water heater?
- Equipment Lifetime
    - Will the product demonstrate a service life comparable to, or exceeding that of conventional gas storage water heaters?
- Operation and Maintenance Implications
    - Are the maintenance requirements comparable to conventional gas water heaters?
    - If additional maintenance is required, how much will it cost, at what interval must it be performed, and can it be performed by the homeowner? (Additional maintenance requirements will adversely affect market acceptance.)

Cost Issues

The SEGWHAI team reviewed existing data on storage water heater costs to better understand the cost implications of potential improvement options. Because of valid proprietary concerns, manufacturers were not asked about the costs of producing SEGWHAI-qualifying products. The following discussion is intended to provide an overview of the industry cost structure to stakeholders who are not involved in the manufacture of water heaters. A U.S. DOE report on residential water heaters (U.S. DOE 2000) presents the 1996 manufacturing cost breakdown (Figure 3-32). Of the total manufacturing cost of approximately $131, roughly $65 is materials cost. Using steel price inflation since 1996 as an approximate yardstick of water heater materials cost escalation, it is reasonable to estimate that materials costs have doubled since 1996. This results in an estimate of the average distributor price of a water heater to $310, which is very close to the current prices offered by discount retailers. However, the cost of Rule 1121 compliance is not known and could be significant. To make the situation more complicated, the price of a water heater to the plumber or consumer is a result of market forces and is not directly tied to cost of production.

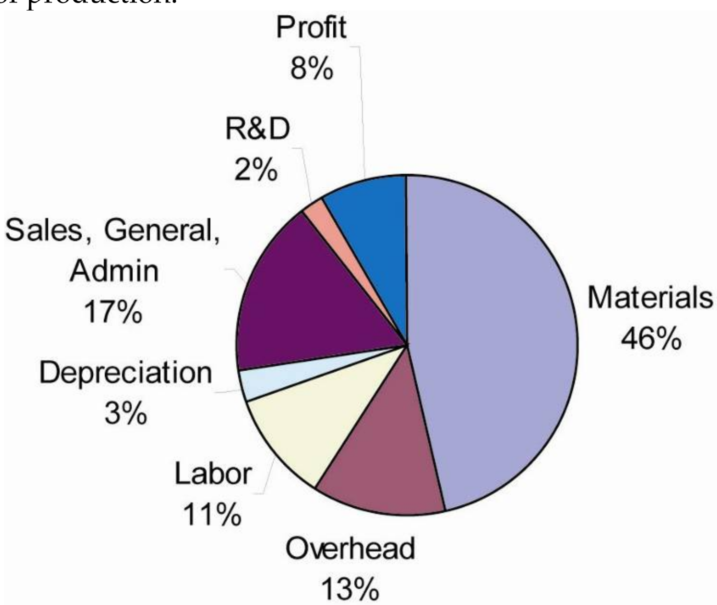

Figure 3-32. Estimated manufacturing cost breakdown for gas storage water heater

The cost of a side arm water heater can be approximated by adding the cost of an electric storage water heater with the cost of a "bare bones" low capacity tankless gas unit. Internet pricing for these tankless units is currently as low as $326.[55] Assuming that the cost of these systems can realistically be reduced by $100 (substituting a less complex control system and gas valve than what is required for a tankless unit, and mass production), the incremental cost for a 40,000 Btuh side arm heater would be approximately $236. This would result in an approximate contractor price of about $550. This type of unit would provide low standby losses, spark ignition, relatively high non-condensing RE, and an EF probably exceeding 0.70.

[55]. For example, see http://www.tanklesswaterheatersdirect.com/shop/tanklesswaterheaters/aquastar/boschaquastar38bbuypage.asp.

3.5.9 Water Heater Component Based Design Options

Clearly, many design paths can lead to a high efficiency storage gas water heater. Some approaches will prove to be too costly, some will have reliability and/or maintenance concerns, and some will result in hot water delivery performance that may not be acceptable to the consumer. All of these considerations factor in to the design of a new high efficiency unit. What is clear is where effort should be expended to improve storage water heater performance. Reducing standby loss by either eliminating the center flue design or eliminating the standing pilot and implementing an effective and reliable flue damper is the key to improving storage water heater efficiency. Combustion efficiency can also be increased in both the non-condensing and condensing efficiency ranges.

To develop a broad framework for evaluating advanced design options, four design decisions that affect water heater efficiency are identified below:

	Design Decision	Options
1.	Location of burner/flue:	Internal (center flue) or external to tank
2.	Combustion efficiency:	Non-condensing or condensing
3.	Combustion air:	Natural or draft induced
4.	Storage tank:	Pressurized or non-pressurized

Although a total of 16 combinations can be developed from these parameters, many of the options are not technically feasible or logical. This framework can be used to facilitate clarity in the prototype development RFP process.

3.5.10 Potential SEGWHAI Product Performance

Based on the considerations presented above, potential technical characteristics of SEGWHAI Tier 1 and 2 products were investigated. Tier 1 is anticipated to use a conventional water heater design as the starting point for energy efficiency enhancements, while Tier 2 products will employ condensing combustion technology in order to boost efficiency levels. An Excel worksheet based on WHAM (Lutz et al. 1999) was used to evaluate potential efficiencies for the two tiers. Results are presented in Table 3-28 and Table 3-29.

For Tier 1, modeling indicates that a conventional water heater in which the standing pilot is replaced with spark ignition and a dampered flue could achieve an EF of 0.72 (Table 3-28). Such a product will probably require an electricity source, but it could be 24 V, making installation easier and less costly. Additional improvements such as increased tank insulation thickness or effectiveness, reducing losses and connection points, and using low leakage flue dampers or induced draft blowers could reduce standby losses by half and increase EF to 0.76. Another option that uses existing technologies is the side arm configuration, in which an electric tank and an external burner are combined. With heat traps, this product could achieve an EF of 0.77.

Table 3-188. Tier 1 SEGWHAI scenarios. All scenarios have: (1) 40-gallon storage capacity; (2) 40,000 Btuh burner input capacity; and (3) intermittent electronic ignition. The spark ignition scenarios would have flue dampers.

Description	Standby Loss Coefficient	RE	Estimated EF
Spark Ignition	3.5	0.80	0.72
Spark Ignition + Max Insulation	1.75	0.80	0.76
Side Arm	1.1	0.80	0.77

Table 3-199. Tier 2 SEGWHAI scenarios. All scenarios have: (1) 40-gallon storage capacity; (2) 40,000 Btuh burner input capacity; and (3) intermittent electronic ignition.

Description	Standby Loss Coefficient	RE	Estimated EF
Helical Internal Flue	3.0	0.90	0.82
Helical Internal Flue + Max Insulation	1.75	0.90	0.85
Side Arm	1.1	0.92	0.89

Technical options for condensing Tier 2 water heaters, and associated efficiencies, are presented in Table 3-29. Modeling indicates that Tier 2 products could achieve EFs in the 0.82–0.89 range. Commercial condensing water heaters are currently available from various manufacturers. For purposes of comparison, in the GAMA product directory, condensing combination water heaters/space heaters are listed with Combined Annual Effective Water Heating Efficiencies (CAef) from 0.78–0.83.

Chapter 4: Conclusions and Recommendations

4.1 SEGWHAI Technical Specifications

4.1.1 Overview

Introduction

This section presents SEGWHAI suggested technical specifications for advanced gas-fired storage water heaters. After considering the water heater market, technical issues, and the environmental impacts of gas water heating, the SEGWHAI team has settled on three key technical specifications: (1) EF, (2) gas input capacity, and (3) NO_X emissions. Appropriate values of these parameters will ensure that water heaters based on SEGWHAI criteria are efficient, clean, inexpensive to install, and cost-competitive.

Background

The Energy Commission's PIER program provided funding for the scoping phase of SEGWHAI. The primary goal of this phase was to develop the technical specifications and programmatic framework for the development of advanced gas storage water heaters that can cost-effectively address both the retrofit and new construction markets in California and throughout North America. The technical specifications provided in this summary section are built upon a set of reports (see Section 3.0 Project Results for further justification) that provide background and context for the SEGWHAI project. These reports provide more background on the SEGWHAI project and the rationale behind the technical specifications.

4.1.2 Technical Specifications

The SEGWHAI technical specifications are summarized in Table 4-1. The SEGWHAI team proposes two efficiency tiers. Tier 1 products will fill the gap between the federal efficiency standard and currently available high efficiency models, while Tier 2 products are envisioned as moderately priced units achieving very high levels of efficiency. SEGWHAI products will also be required to meet all relevant safety standards. All tank sizes will be eligible to participate in SEGWHAI, though the primary target of the program is 40- to 50-gallon water heaters, since these are the most common residential units.

Table 4-1. SEGWHAI technical specifications

	Tier 1	Tier 2
EF	≥0.70	≥0.82
Gas input (Btuh)	≤40,000	≤40,000
NO_X Emissions (ng/J)	≤10	≤10

EF is a measure of overall water heater efficiency, and is defined by the U.S. DOE's Energy Conservation Standards for Water Heaters, 10 CFR Part 430 Subpart B, Appendix E, Sections 1.4 and 6.1.7 (U.S. DOE 2001). The test procedure is described in Section 5.1.5 of the same document, and involves a set of six 10.7 gallon water draws spaced at 1 hour intervals, followed by recovery for 19 hours.

Gas input is the rate at which the water heater uses natural gas. The test procedure for measuring gas input is described in 10 CFR Part 430 Subpart B, Appendix E, Section 5.1.3.[56] NO_X emissions, in ng/J of water heated, are calculated per the SCAQMD Protocol on Nitrogen Oxide Emissions Compliance Testing for Natural Gas-Fired Water Heaters and Small Boilers (amended January 1998), Section 8.

4.1.3 Rationale for Specifications

EF Tiers

SEGWHAI began with a vision of filling the market gap between conventional storage gas water heaters with EF around 0.60, and high cost tankless and condensing products with EF 0.80 and above. A 30% increase in the EF of storage water heaters, to 0.78 or 0.80, was targeted as being achievable without the need for a condensing operating cycle or substantially improved heat exchangers. Discussions with SEGWHAI participants have led to the conclusion that it is more realistic to establish two performance tiers than to develop a single performance standard.

Potential SEGWHAI Product Performance shows that SEGWHAI Tier 1 products could feasibly achieve EFs between 0.72–0.77, and Tier 2 products could achieve EFs from 0.82–0.89. The recommended EF standards of 0.70 for Tier 1 and 0.82 for Tier 2 are therefore reasonable.

Gas Input Capacity

Virtually all conventional gas storage water heaters in the SEGWHAI target range of 40–50 gallons have capacity burners rated at ≤40,000 Btuh.[57] Since the large majority of residential gas water heaters sold are replacement units, and replacing gas lines can be prohibitively expensive, SEGWHAI units must not exceed this gas input capacity. The purpose of this requirement is to avoid the situation of high efficiency tankless gas water heaters, which require up to five times the gas capacity of storage units and are thus have extremely high retrofit costs.

An additional reason for limiting SEGWHAI units to 40,000 Btuh is that large capacity water heaters can encourage increased hot water use, reducing the energy savings achieved by efficient products.

NO_X Emissions

The combustion of natural gas releases NO_X, a harmful air pollutant. Beginning in January 2008, the NO_X emissions of residential water heaters sold in the California SCAQMD will be limited to 10 ng/J of heat output. The SCAQMD rule will affect 40% of the California water heater market, and a dozen other California air districts are expected to follow SCAQMD’s lead in the next few years. Since a significant fraction of the national water heater market will soon be

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[56]. CFR refers to this as “power input” rather than “gas input.” This report uses the term “gas input” in order to emphasize that SEGWHAI is directed only at gas water heaters and does not include electric products.

[57]. In the GAMA product directory (GAMA 2006), 94% of the models of 40-gallon residential gas water heaters and 66% of 50-gallon residential gas water heaters have gas input rates of ≤40,000 Btuh.

covered by a 10 ng/J NO_X emissions limit, it is reasonable to require all SEGWHAI products to meet this requirement as well. See Section 3.0 Energy and Environmental Benefits for further discussion of this topic.

4.2 Prototype Competition Plan

4.2.1 Background

SEGWHAI was envisioned to include the following phases:

- Scoping
- Prototype development
- Emerging technology laboratory and field testing
- Mass market pilot testing
- Mass market implementation

The SEGWHAI scoping phase has assembled a partnership of stakeholders including utilities, government entities, energy efficiency advocates, and water heater manufacturers for the express purpose of accelerating the development of cost-effective, high efficiency residential gas water heaters. The scoping phase also developed recommendations to accomplish the SEGWHAI mission. This document is the result of the scoping phase.

Figure 4-1 shows the four SEGWHAI phases that follow the scoping phase, along with expected participants and a potential timeline. As an outcome of the scoping phase, the remaining phases are now envisioned as overlapping rather than strictly sequential. For instance, manufacturers with market-ready technologies would not need to begin with the prototype development phase, but may enter the program as far along as the mass market pilot testing phase. The dates and entry points shown in Figure 4-1 are for purposes of illustration only.

While the roles and functions of these phases are discrete, their schedules will overlap. Such overlap occurs because the program is intended to expedite the implementation of an array of technologies, each of which may proceed on its own schedule.

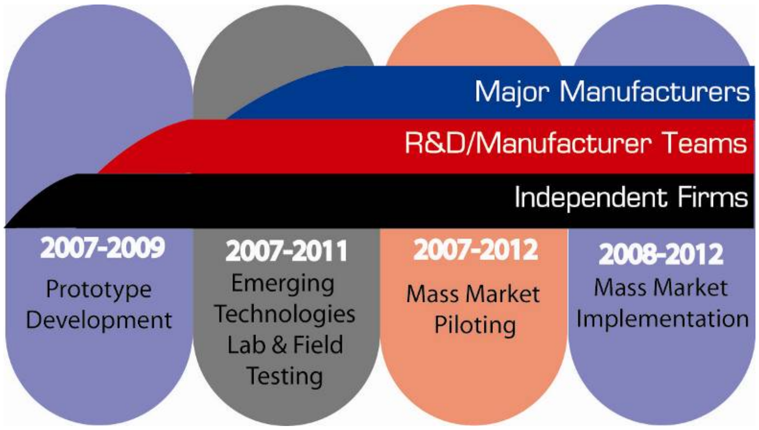

Figure 4-1. SEGWHAI phases

The prototype development phase will include a competitive solicitation to develop advanced water heater designs. These designs, along with others, will be eligible for monitored emerging technology field and laboratory testing. Emerging technology testing will be funded by utilities, and is anticipated to involve several hundred units from each manufacturer.[58] This phase allows the utilities and manufacturers to verify product reliability, efficiency, and NO_X emissions under a variety of field conditions. The reliability of new technologies is critical for customer satisfaction; long-term energy efficiency is important to energy efficiency program administrators; and low NO_X performance is important to SCAQMD and other air quality management districts.

Products that are successful in the emerging technology phase can progress to the mass market pilot phase. This phase is where manufacturers, distributors, discount retailers, and plumbers work with gas utilities to test program design strategies, such as those discussed in Section 3.4 Roadmap for Commercialization, Outreach and Marketing. Pilot programs allow the utility and regulators to assess which program elements will work best in each situation. For instance, a different type of program is necessary to get a discount retailer to stock and sell a super efficient water heater at a reduced price than is required to ensure that distributors stock and sell the same product to plumbers.

A fully functioning mass market incentive program for water heaters meeting SEGWHAI criteria would have the statewide goal of paying incentives for hundreds of thousands of unit/yr. The program would ramp up to its full size over several years, given that it proves cost-effective. To be eligible for this phase, water heaters must be available in large numbers over many years.

4.2.2 Prototype Development Goals

The primary goal of the prototype development phase is to sponsor the development of advanced, cost-effective residential gas storage water heating technologies that otherwise would reach the market much later, or not at all.

The development and distribution of a RFP will foster awareness of the SEGWHAI technical specifications and development opportunities by creating and advertising a competitive solicitation directed at a wide range of firms. The RFP will need to be structured to maximize the probability that viable products will be taken to production in sufficient numbers to be used in emerging technology field testing.

4.2.3 Prototype Concept Alternatives

The approach of the prototype development phase has evolved in the course of SEGWHAI scoping. Initially, the SEGWHAI team viewed prototype development as essential to program success. Prototype development was to be a necessary step along the path to mass

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[58]. Some utilities may be willing to skip the emerging technologies phase as long as they have reliable evidence of product performance, such as EFs listed in the GAMA directory.

commercialization of high efficiency gas water heaters. During the scoping process, however, a different view has emerged.

Three major changes from the anticipated plan have resulted from contacts with residential storage gas water heater manufacturers and are shown below:

- After recent mergers and acquisitions, only three major residential manufacturers remain, and none of the three has expressed significant interest in responding to a competitive solicitation. All indicate that they are working on higher efficiency designs, but these firms are more interested in the support they might receive for mass marketing than for prototype development. This response convinced the authors that it makes sense to allow each product to follow its own "best path" through the process to the mass market. A manufacturer might have different products in several phases at the same time, allowing them to bring some products to the market as soon as possible.
- The second major change resulted from the fact that limited R&D funds are available. Thus, the solicitation should focus on the ultimate prize: the Tier 2 SEGWHAI unit, with condensing water heater performance (EF ≥0.82). While condensing water heaters are currently available in the marketplace, they are all produced in low volumes and are high-capacity units best suited for commercial applications or for residential combined space and water heating loads. These units usually cannot be installed as direct replacements using the existing gas line, and they are considerably more expensive than conventional water heaters. The prototype RFP will solicit bids for the missing piece: a ≤40,000 Btuh condensing storage water heater.
- The third major change stems from both the current limited availability of funds and the potential benefits of extending the prototype development schedule to allow further developments in water heater design and materials. Although some existing condensing water heater designs can be downsized and configured to meet SCAQMD NO_X requirements in less than a year, more advanced lower-cost designs will likely take longer and require more manufacturer commitment. These advanced designs might, for example, use nonmetallic, unpressurized storage tanks, as well as other improvements that increase cost-effectiveness compared to scaled-down versions of existing condensing water heater designs. For these reasons, SEGWHAI proposes a two-step solicitation, splitting the R&D funding into halves. In this way the program can begin prototype development sooner and at lower expense, with the goal of fostering early entries aimed at the small condensing heater market. Meanwhile, experience with the first solicitation along with R&D efforts taking place in related areas can result in a subsequent, enhanced solicitation designed to elicit further advances, while better utilizing project budget and personnel resources. Thus, even if full R&D funding were available in the short term, the two-step process would be recommended since advanced designs may not be available for a few years.

4.2.4 Scope of Solicitation

The intended audience for the prototype solicitation is comprised of the following:

- Three major residential water heater manufacturers
- Other storage and non-storage water heater manufacturing entities
- Innovative product development firms with connections to large-scale manufacturing entities

A key requirement for any prototype development funding recipient is a demonstrated link to a large-scale manufacturing entity with the experience and commitment to deliver product to the marketplace. Though major manufacturers may choose not to participate in the prototype phase on their own, they may benefit from participating in teams led by product development firms. This model led to the successful development of the Vertex unit (see Section 3.5.7 Advanced Water Heater Development Case Studies).

The technical specifications for the prototype solicitation are based on the Tier 2 condensing level performance, since this is where SEGWHAI can effectively serve as catalyst between the suppliers and the incentive-driven market. These specifications require a Rule 1121 compliant unit with a minimum EF of 0.82 (see Section 4.1 Technical Specifications). Utilities and other funders may include additional requirements as needed to meet their long-term goals.

4.2.5 Prototype RFP Planning

The current SEGWHAI budget provides for completion of scoping activities. The lack of continuing funding at this time precludes development of a detailed prototype RFP plan and schedule. A new alliance of stakeholders will need to be established to develop the RFP. This will involve establishing a "water heating institute" to implement the prototype development program, or finding an existing organization to take on this role. Due to the lead-time necessary for securing funding and establishing the committee, the RFP will realistically be released no sooner than the fourth quarter of 2007. This timeline appears to mesh well with the current product development efforts of the manufacturers, who are focused on getting Rule 1121 compliant water heaters to the market by the end of the third quarter of 2007. Once development and implementation efforts are completed for NO_X compliance, manufacturers may be able to focus R&D resources on developing a SEGWHAI Tier 2 water heater. This schedule will also allow additional funding sources to be identified before the prototype development phase begins.

Preliminary analysis suggests several possibilities for the prototype development process. Ideally, multiple prototype development contracts would be issued in each solicitation to promote alternate design strategies and competitive approaches towards developing cost-effective high efficiency products. It is anticipated that funding support on the order of $250,000–$400,000 per selected team will be required. If two bidders were selected, required grant funding would be in the $500,000–$800,000 range. In addition, there are also the costs of administering the program and supporting the program stakeholder committee. It is important obtain broad-based funding support to signal to the industry that interest in this type of high efficiency water heater is widespread.

Expected project duration is roughly 30 months for each of the two solicitations, though they may overlap by 6–12 months. At the end of each prototype phase, the participants would have demonstrated Tier 2 compliant units that have satisfied internal manufacturer quality control standards, all applicable safety standards, and the SEGWHAI technical specifications. These products would then be eligible for emerging technology testing.

4.2.6 Prototype Development Benefits

Directing the prototype effort at the SEGWHAI Tier 2 performance level is intended to accelerate development of lower-cost, high efficiency products in recognition of the fact that current condensing water heaters are not aimed at the residential replacement market. The prototype development solicitation will signal the need to transform the water heater market toward cost-effective high efficiency products and that funding is available for those who want to be involved. If SEGWHAI can accelerate the implementation of advanced water heating technologies by a few years, it will generate energy and environmental benefits that otherwise would have been lost for the 10- to 15-year water heater replacement cycle of individual consumers. A detailed discussion of projected SEGWHAI benefits can be found in Section 3.0 Energy and Environmental Benefits.

4.2.7 Next Steps

The short-term objective is to secure funding for prototype development activities. Various parties including the Energy Commission and NYSERDA have expressed interest in providing limited funding. Other potential funding sources include the U.S. DOE, the U.S. EPA, NRCan, and natural gas utilities. Funding from foundations and venture capital firms should also be pursued. A collaborative funding approach could result in a broad-based North American effort to promote the goal of improved water heating efficiency and reduced combustion emissions. With funding committed, the prototype development team should draft a solicitation for circulation. In parallel with solicitation development, the prototype development team will continue making industry contacts with the goal of identifying potential design/manufacturing teams. Funding stakeholders could decide to keep SEGWHAI in operation to implement the prototype phase. A "water heating institute" or other successor to SEGWHAI should continue to serve as a focal point for collaboration, coordination, and administration of efforts to foster the next generation of efficient residential water heaters.

4.3 Conclusions

The initial SEGWHAI objectives were as follows:

- Establish a Steering committee of project stakeholders to be engaged in developing criteria for super efficient residential storage gas water heaters for replacement and new construction applications.
- Conduct a series of Steering committee meetings to establish consensus and build understanding amongst stakeholders. Support Steering committee activities through project research, outreach materials, and a communications website.
- Develop the criteria for super efficient water heating appliances.

- Produce a final report that establishes the rationale and foundation for the proposed criteria.
- Make recommendations for future work and initiatives regarding residential storage natural gas hot waters.

The SEGWHAI PIER funded scoping phase accomplished its objectives by establishing a Steering committee of stakeholders, completing research for the topics discussed in this final report, building consensus amongst stakeholders, and making recommendations for future activities.

SEGWHAI findings indicate that adoption of performance-based technical specifications, such as SEGWHAI Tier 1 and Tier 2 standards, have the potential to fill an existing market gap and introduce significantly more efficient gas storage water heaters. Utilizing a public, open access approach, SEGWHAI created a network of stakeholders, supported by technical documentation and analysis. The stakeholder network possesses the resources and motivation to develop and introduce SEGWHAI-based products. Implementation of SEGWHAI efficiency tiers is feasible and has the potential to significantly reduce natural gas consumption and CO_2 and NO_X emissions throughout North America. Additional funding for incentive programs and implementation of a prototype development phase will increase the natural gas and emissions savings potential.

Table 4-2 outlines the initiative's final findings and conclusions for the decisions that were made. All conclusions were developed by the authors with significant input from the Steering committee.

Table 4-2. SEGWHAI Findings and Conclusions

Findings	Conclusion
Procuring technology performance-based technical criteria accelerates the process of bringing products to the market by not encumbering the process with the overhead of a competition.	SEGWHAI is a technology procurement process using technical criteria
Performance-based criteria allows for flexibility and a variety of technical solutions. Manufacturers know their market, so additional specifications are not necessary.	SEGWHAI-based criteria are limited to EF, burner capacity, and NO_X performance
Achieving EF 0.78 is judged to be infeasible with non-condensing burners at 0.82 RE. Natural Gas appliances have a necessary gap of about 10% between non-condensing and condensing technologies. Almost all replacement sites are suitable for non-condensing units, but condensing units require condensate drains and 110 V power that make installation costs high. Products with EF 0.67 are on the market today, and WHAM runs show that 0.70 and 0.82 are feasible with reasonable standby losses. The federal tax credit level is set at 0.8 and may go higher.	Two Tiered SEGWHAI-based performance criteria Tier 1: EF 0.70 Tire 2: EF 0.82
In California, at least 40% of the population is covered by SCAQMD Rule 1121. Other AQMDs will be following with the same criteria. More than 55% of U.S. citizens live in eight hour ozone non-attainment areas, all of which need NO_X emission reduction. Clarity and economies of scale are maximized adopting the same criteria for all units, no matter where they are sold.	SEGWHAI-based criteria includes super low NO_X criteria specifications
Other organizations can successfully represent stakeholder interests with efficiency tiers for residential gas storage water heaters. A new organization takes time and money to establish and run.	The tiers developed by the SEGWHAI project are made available for other programs to use in developing a gas storage water heater initiative
The SEGWHAI Steering committee process has established a functioning network of stakeholders. Many important issues to be addressed are remaining, such as hot water distribution, hot water system inefficiencies in restaurants, and the impact of hard water on longevity and efficiency. Stakeholders can fund the continuation of this network at low-cost through a water heating institute located within the Energy Efficiency Center at the University of California Davis, using the website and other materials developed in the course of the SEGWHAI-scoping phase.	Future stakeholder coordination, forums, and prototype development are managed by a neutral third party organization.

Findings	Conclusion
Manufacturers plan to introduce SEGWHAI qualifying without going through the prototype phase. Thus prototypes are not on the critical path. Funding sources will take time to develop, and time is needed to work with stakeholders to clarify what the focus of the prototype RFP should be. A reasonable goal is fall 2007. Prototyping can then be focused on overcoming barriers to low-cost Tier 2 units or concentrating on components common to all water heaters. Energy efficiency and solid waste concerns drive the need for water heaters that last 20 years or longer.	Prototype Competition delayed to fall 2007 and until funding and focus are defined
Manufacturers can produce products without prototype funding to enter at the emerging technology or mass market phases. Rapid deployment requires flexibility. Utilities in California are ready with emerging technology and mass market pilot testing.	Multiple entry points to the market for water heaters meeting SEGWHAI criteria

4.4 Recommendations

The initial phase of SEGHWAI established program viability and justified ongoing activities in the residential hot water sector. Project activities contributed to understanding the challenges of implementing a major shift in water heater efficiency, and demonstrated the need to continue working toward the objective of cost-effective high efficiency storage water heaters. The following recommendations are both SEGWHAI specific and applicable to general water heating advancements. A total of 1.68 quadrillions (Quads) of energy is consumed heating water in the United States. With proper attention, energy efficiency and water conservation can generate savings of up to 30%. Implementation of the recommendations made in this report can facilitate the successful transformation of the residential water heater market by increasing the installed efficiency of water heaters from 60% to 75% over the next 10–15 years. This will require the rapid development and introduction of SEGWHAI-based high efficiency water heaters for the new construction and replacement markets.

Recommendations

- This initial scoping phase of SEGWHAI provides the specific recommendations as follows:
- Adopt SEGWHAI tiered energy efficiency performance criteria and an ULN emission standard for water heaters throughout North America.
- The SEGWHAI technical criteria should be made available for its use by other organizations in developing an initiative for advanced residential storage gas water heaters.
- Participants should commit to funding incentive programs lasting at least five years.
- Utilize SEGWHAI tiers in establishing new ENERGY STAR* specifications for storage gas water heaters.

- Modify EPact 2005 federal tax credit for water heaters legislation to include products that meet or exceed tiers established by SEGWHAI with funding for a period of five years or longer.
- Establish side by side testing of water heater performance using realistic hot water draw patterns, and use this testing to assess the NO_X emissions of standing pilot lights and the level and variability of NO_X production during a variety of draw patterns.
- Coordinate with SCAQMD to develop credit for water heaters that meet SEGWHAI based criteria and reduce NO_X emissions as a result of standing pilot light elimination.
- Include SEGWHAI specifications as part of the High Efficiency Residential Gas Water Heater Program for the CPUC Big, Bold Initiatives for 2009–2011 (Section 3.4.6., California State Energy Efficiency Policy Initiatives)

4.4.1 Additional Recommendations

In the process of the developing SEGWHAI, the authors developed recommendations to address other important issues in the advancement of the residential hot water field. These additional recommendations are as follows:

- Conduct field research to assemble comprehensive data on actual hot water usage. Use actual data to modify test standards and develop consumer friendly analysis of the energy economics involved in water heater selection.
- Conduct field research to develop a statistically valid assessment of the characteristic of water heater installations.
- Establish a "water heating institute" to conduct R&D of prototype units, foster distribution system best practices, continue to support the stakeholder network established by SEGWHAI, and conduct other studies as determined by the interest and funding of the stakeholders.
- Conduct a domestic water heating forum in fall 2007 to bring together industry leaders.
- Develop a new energy efficiency test standard to replace the existing EF test. New test procedures should allow end users to compare the performance of different technologies.
- Expand knowledge of hot water draw schedules through the implementation of a stratified statistical sample of North American households.

4.5 Benefits to California

California will benefit from the implementation of a SEGWHAI-based water heater efficiency program in the following ways:

- Reduce water heating costs for California homeowners
- Contribute to the State of California goal of reduced CO_2 emissions
- Improve air quality through reduced NO_X emissions
- Save millions of therms in support of the energy efficiency goals of PG&E, SoCalGas, and SDG&E

- Strengthen reputation as the nation's leader in energy efficiency

Over the lifetime of SEGWHAI compliant water heaters, each unit has the potential to save between 400–700 therms, reduce CO_2 emissions by 2.4–4.1 M/T, and avoid up to 13 pounds of NO_X emissions. If 50% of existing water heaters in the state were replaced with SEGWHAI Tier 1 units, California households would save more than $154 million each year in natural gas costs, and the state would avoid annual emissions of more than 900,000 M/T of CO_2 and nearly 5 million pounds of NO_X. The CPUC values these emission reductions at more than $30 million/yr (E3 2006b). The more aggressive program envisioned in response to the CPUC Big, Bold Initiative will result in even more savings while remaining cost-effective.

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Chapter 6: Glossary

Specific acronyms used throughout this report are defined as follows:

ACEEE	American Council for an Energy Efficient Economy
AGA	American Gas Association
ANOPR	Advance Notice of Propose Rulemaking
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AQMD	Air Quality Management District
BCR	Benefit-Cost Ratio
Btu	British thermal unit
Btuh	British thermal units per hour
CAef	Combined Annual Effective Water Heating Efficiencies
CDA	Conditional Demand Analysis
CLASS	California Statewide Residential Lighting and Appliance Efficiency Saturation Study
CO_2	carbon dioxide
CPUC	California Public Utilities Commission
DEER	Database for Energy Efficient Resources
E3	Energy and Environmental Economics
ECO	emergency cut-off
EF	energy factor
Energy Commission	California Energy Commission
EPact	Energy Policy Act
FVIR	flammable vapor ignition resistant
GAMA	Gas Appliance Manufacturer's Association
GRI	Gas Research Institute
GTI	Gas Technology Institute
IMC	incremental measure cost
LBNL	Lawrence Berkeley National Laboratory

LDO	lint, dust, and oil
M/T	metric tons
NAAQS	National Ambient Air Quality Standard
NAECA	National Appliance Energy Conservation Act
NAECAS	National Appliance Energy Conservation Act Standards
NEEA	Northwest Energy Efficiency Alliance
N_2	nitrogen
NO_X	oxides of nitrogen
NRcan	Natural Resources Canada
NRDC	Natural Resources Defense Council
NYSERDA	New York State Energy Research and Development Authority
O_2	oxygen
PG&E	Pacific Gas and Electric
PIER	Public Interest Energy Research
Quad	One quadrillion Btus.
RASS	Residential Appliance Saturation Survey
RE	Recovery Efficiency
R&D	research and development
RFP	Request for Proposals
RECS	Residential Energy Consumption Survey
SDG&E	San Diego Gas and Electric
SEGWHAI	Super Efficient Gas Water Heating Appliance Initiative
SERP	Super Efficient Refrigerator Project
SCAQMD	South Coast Air Quality Management District
SoCalGas	Southern California Gas Company
TE	thermal efficiency
TPR	temperature and pressure relief
TRC	total resource cost
UA	Standby heat loss coefficient
UEC	Unit Energy Consumption

ULN	Ultra Low NO_x
U.S.	United States
U.S. DOE	United States Department of Energy
U.S. EPA	United States Environmental Protection Agency
V	volt
WHAM	Water Heater Analysis Model

Specific terms used throughout this report are defined as follows:

Word	**Definition**
British Thermal Unit	The amount of heat required to increase the temperature of a pound of water by 1°F
Condensing Water Heater	A gas fired water heater designed to transfer heat from combustion gases cooling them to the point where water vapor condenses into a liquid inside of the water heater (to be drained away for disposal) thereby achieving recovery efficiency in the 90% range.
Decremental cost	That part of the cost of producing energy which could be avoided if demand for that energy didn't exist or if alternate energy supplies were available. Decremental cost refers only to the cost of producing the energy, and differs from avoided cost which refers to all fixed costs whether or not they are related to production, as well as costs related to depreciation of assets and other expenses.
Effective Useful Life	The lifetime of an average water heater
Energy Factor	The measure of the overall efficiency of a water heater based on the model’s recovery efficiency, standby losses, and energy input.
ENERGY STAR*	An effort jointly administered by the U.S. EPA and using a U.S. DOE specified test procedure.
Incremental cost	The cost of the next kilowatt-hour of generated energy. Incremental costs change as production increases or decreases, but these changes don't always occur in a predictable pattern. As an example, incremental costs typically decrease as production rises to comfortable capacity. But once that limit is reached, incremental costs increase because additional costs (construction of new facilities, costs of stressing production facilities, etc.) need to be factored into the cost of the next unit.

Word	Definition
Gas Input	The rate at which a water heater uses natural gas
joule	A standard measure of energy equivalent to a watt-second, or 1/3,600,000th of a kilowatt-hour
Levelized Cost	The present value of the total cost of operating a program over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation)
MONEL®	A metal alloy of iron, copper and nickel used in the production of water heaters only occasionally. Most modern water heaters are made of glass-lined mild steel.
Nanogram	One billionth (10^{-9}) of a gram
Nitrous Oxide	A class of polluting emissions produced by the combustion of fossil fuels
Non-Condensing Water Heater	A gas fired water heater designed limit heat transfer to keep combustion gases hot enough so that water vapor, a major component of combustion, does not condense inside the water heater or outside in the flue that carries combustion gases away thereby achieving recovery efficiency in the 80% range.
Quad	A unit of energy equal to 10^{15} BTU
R-value	A measure of thermal resistance in heat transfer problems
Recovery Efficiency	The ratio of heat absorbed by the water to heat input to the heating unit during the period that the water temperature is raised from inlet to final temperature.
Rule 1121	A regulation established in 1978 and updated in 2004 by SCAQMD limiting NO_x emissions from residential water heaters in the South Coast air basin of Southern California
Standby Loss Coefficient	The mathematical product of the area of heat transfer and the resistance to heat transfer. In the DOE test procedure this is calculated by the energy consumption during the standby period of the test, not by multiplying surface area by heat transfer coefficient.
Therm	A unit of heat energy equal to 100,000 British thermal units
Title 20	A commonly used term to refer to the Energy Commission Appliance Efficiency Standards. Since 1977 the Title 20 Appliance Standards have set mandatory efficiency levels that dozens of

Word	**Definition**
	appliances must meet before they can be sold in California. Title 20 adopts federal standards for those appliances covered by DOE and has a number of additional standards for appliances that are not covered.
Title 24	A commonly used shorthand reference to the Energy Commission Building Energy Efficiency Standards that are developed and adopted on a three year cycle. Title 24 focus on Energy Building Regulations and Efficiency Standards for the California Code of Regulations.
Total Resource Cost	A benefit-cost test which measures the net costs of a demand-side program as a resource option based on the total costs of the program, including both the participants' and the utility's costs. The benefits for the TRC are avoided supply costs (avoided credit and collection costs should also be included, as they are system costs). The costs in this test are the program costs (including equipment costs) paid by the utility and the participants plus the increase in supply costs for any period in which load has been increased.
Unit Energy Consumption	The annual energy consumption of a device
Volt	The International System unit of electric potential and electromotive force, equal to the difference of electric potential between two points on a conducting wire carrying a constant current of one ampere when the power dissipated between the points is one watt
Water Heater Analysis Model	An energy equation developed by Lawrence Berkeley National Laboratory, which calculates water heater energy consumption by taking into account seven parameters: recovery efficiency, standby heat loss coefficient, rated input power, average daily hot water draw volume, inlet water temperature, thermostat setting, and air temperature around the water heater

Appendix A.

Gas Water Heater Installation Field Survey

Gas Water Heater Installation Field Survey

Today's Date______________________

Surveyor's Name___________________

SITE INFO

Street Address_________________

City__________________________

State_________________________

ZIP Code______________________

Year House Was Built____________

INSTALLED IN (circle one): Garage • Laundry Room • Kitchen • Attic

STATUS (CIRCLE ONE)

Tank Insulation Type: None • Fiber • Foam

Exterior Blanket: yes • no

Flue connected to: not connected • chimney • separate stack • shared stack

Temperature & Pressure Relief valve: yes • no

TPR valve plumbed outside: yes • no
Drain Pan: yes • no

Drain Pan plumbed to outdoor: yes • no

Estimated age (years): 1 • 2 • 3 • 4 • 5 • 6 • 7 • 8 • 9 • 10 • 11 • 12 • 13 • 14 • 15+

Picture (house #, water heater): yes • no

Condensation / Leakage evidence:

Rust? Yes • no

Where? (circle all that apply) top of tank • bottom of tank • plumbing • vent pipe

Earthquake straps (2 straps) yes • no

Flammable (paper, fumes) materials stored within 1 foot? yes • no

If in garage:

Bollard yes • no
Platform, higher than 18" above floor? yes • no

NAMEPLATE DATA (to extent available)

Brand / Maker: ____

Model Number: ____

Serial Number: ____

Capacity -gallons (circle one) 30 gal • 40 gal • 50 gal • Other:________gal

Natural Gas Input - kBtuh: ___________________

Explosion Resistant Design yes • no

COMBUSTION (INTAKE) AIR

Size of Room/Closet __________ft L x______________ ft W x_____________ft H

If "small room", inlet type? (circle one) : Screen • Louver • Other_______________
# of vents (circle one): 1 • 2 • 3 +
Vent sizes (all of them):_________in L x ________in W ; _________in L x ________in W
Appliances in same room (circle all that apply): dryer (gas or electric) • furnace
• other gas appliances or other appliances with exhaust fan:______________________

CONNECTIONS

Cold Water-In: Size 3/4 inch • other:_____________inch

Flexible yes • no

Shut-off Valve yes • no

Heat Trap hard S pipe • integrated valve • other:___________

Hot Water-Out: Size 3/4 inch • other:_____________inch

Flexible yes • no

Shut-off Valve yes • no

Heat Trap hard S pipe • integrated valve • other:___________

FLUE (skip if no flue)

Type (circle one) natural vent • direct-vent • powered vent

(natural or power vent) draft diverter? yes • no

Diameter Size - inches 3 • 4 • 5 • other__________________

Material (circle one) single wall metal • dual wall metal • asbestos • plastic • other___________________________

Run

total height above unit ___________ft

# of 90° elbows (circle one) 1 • 2 • 3 • 4 +

# of 45° elbows (circle one) 1 • 2 • 3 • 4 +

Termination (circle one) roof in the clear • lower roof w/ structure above • side wall • other:______________________

MODIFICATION ASSESSMENT

Gas Supply: Distance to gas meter _________ ft

Distance to 3/4" gas line _________ ft

Modification needed from ¾'' gas line (circle all that apply): direct • exposed • <19 ft • >10 ft • thru floor • thru finished ceiling • thru exterior wall •

from gas meter • other___________________

Electrical: Distance to 110 outlet _________ ft

Run from 110V outlet across wall or ceiling (for 24V transformer)______ ft

Flue modification possibilities (circle all possible to do for modification)

Straight up, exposed ceiling • Straight up, through hard/finished ceiling

• Under second story • Can combine stack with other nearby gas flue

• Side wall potential (not w/in 4 ft of operable windows or under operable window)

Condensate tubing run: Direct to outside • Length of run _____

Condensate pump • Length of run _______.

Appendix B.

Results of the SEGWHAI Manufacturer Survey (September 2006)

Results of the SEGWHAI Manufacturer Survey (September 2006)
Compiled by Frank Stanonik, GAMA
Manufacturer Questions:

ID	Question	Options	Response/Comments
Current Market Plans			
1	In the absence of SEGWHAI support, when does your company plan to introduce a water heater that will achieve EF ≥0.68?	1st Quarter 2007 3rd Quarter 2007 1st Quarter 2008 Other No plans **Decline to State**	**6. Decline to State**
2	In the absence of SEGWHAI support, when does your company plan to introduce a condensing gas storage water heater unit that will achieve EF ≥0.80?	1st Quarter 2007 3rd Quarter 2007 1st Quarter 2008 Other No plans **Decline to State**	**6. Decline to State**

Accelerating Market Introduction			
3	What activities should be pursued to accelerate the introduction of higher efficiency models? (Please rank in order of importance)	-Prototype development and testing funding -Create market demand for more expensive and efficient models -Provide ENERGY STAR* branding for water heating -Conduct & widely report independent 3rd party field and laboratory testing -Conduct utility rebate programs for customers -Conduct utility rebate programs for distributors -Conduct utility rebate programs for installers -Conduct utility rebate programs for manufacturers -Conduct utility rebate programs for big box retailers -Create tax credits for the models	**2*.** Provide ENERGY STAR* branding for water heating **2***. Conduct utility rebate programs for customers **3.** Create tax credits for the models **4*.** Create market demand for more expensive and efficient models **5.** Conduct utility rebate programs for installers **6.** Conduct utility rebate programs for distributors **7.** Prototype development and testing funding **8.** Conduct utility rebate programs for manufacturers (No Response) -Conduct utility rebate programs for big box retailers ***Ranked #1 by a Respondent***
4	How interested are you in SEGWHAI prototype R&D funding for developing a low cost, low burner capacity (40k Btuh, ½" house gas supply) EF ≥0.80 condensing unit for the replacement market?	Not interested **Interested** Very interested	**(-)* 2. Interested** ***Not unanimous.*** ****(-) indicates less interest***
5	Energy Efficiency program managers have indicated that field testing is an important step in demonstrating product efficiency and performance. Positive field test results are likely to result in stronger financial support from utility and efficiency programs. How interested are you in participating in a publicly supported Emerging Technology field demonstration[59] for a replacement, high efficiency (EF≥0.68), non-condensing model?	Not interested **Interested** Very interested	**(+)* 2. Interested** ***Not unanimous.*** ****(+) indicates more interest***

[59] Anticipated to involve several hundred units from multiple manufacturers, with continuing confidential feedback to each on its own units.

6	How interested are you in participating in a publicly supported emerging technology field demonstration for a replacement, high efficiency (EF≥0.80), condensing model?	Not interested **Interested** Very interested	**(+)* 2. Interested** ***(+) indicates more interest**
7	In your opinion, how many units per model would be considered a representative sample for a field test program?	10–50 units **50 – 200 units** More than 200 units	**2. 50 – 200 units**
8	SEGWHAI is considering the potential and benefits of pilot incentive programs. These would be designed to install a few thousand units in a year or less. With SEGWHAI support, when will you have an EF≥0.68 product that can be introduced to the market?	1st Quarter 2007 3rd Quarter 2007 1st Quarter 2008 Other No plans **Decline to State**	**6. Decline to State**
	With SEGWHAI support, when would your company be ready to introduce an EF≥0.80 product for a similar size pilot program?	1st Quarter 2007 3rd Quarter 2007 1st Quarter 2008 Other No plans **Decline to State**	**6. Decline to State**
Incentives			
9	Financial incentives can be given to different market actors. Which do you believe work best? (If you check more than one, please provide comments)	Manufacturers Distributors of Discount Retailers Plumbers **Customers**	**4. Customers**
10	SEGWHAI Mass Market programs would provide incentives for tens (or hundreds) of thousands of units a year. If you were to participate in such a program, when would your company be able to provide sufficient EF ≥0.68 product?	1st Quarter 2007 3rd Quarter 2007 1st Quarter 2008 Other No plans **Decline to State**	**6. Decline to State**
	When would sufficient EF ≥0.80 product be available?	1st Quarter 2008 3rd Quarter 2008 1st Quarter 2009 Other No plans **Decline to State**	**6. Decline to State**

11	SEGWHAI plans to facilitate market introduction by providing incentives for hundreds of thousand SEGWHAI compliant units. In your opinion, what is the minimum number of units necessary to establish the market (assuming that there will be multiple qualified models from multiple manufacturers)?	Number of units per year_____ (or) Percent of total water heating market sales _____	**Number of units per year: 50,000+**
12	In your opinion, what is the minimum number of years that the incentives need to be available to give a good probability that we can permanently transform the market?	1 year 2 years 3 years 4 years **5 years** Other Decline to State	**5. 5 years (+)** ***One respondent suggested more than 5 years***.
13	At present, utilities in California provide incentives of $30 for storage water heaters with an EF ≥0.62. Would your firm be interested in manufacturing 40-gallon gas-fired water heaters with EF ≥0.68 for incentives of ~$80 per unit?	**Yes** No Decline to State	**(-)* 1. Yes** ***One respondent suggested that the incentive should be higher*** ****(-) indicates less interest***
14	Would your firm be interested in manufacturing 40-gallon gas-fired water heaters with EF ≥0.80 for incentives of ~$200 per unit?	**Yes** No Decline to State	**(-)* 1. Yes** ***See comment for Q.13*** ****(-) indicates less interest***
Emissions			
15	SEGWHAI is considering requiring all qualifying units to meet Rule 1121. How much time (from January 2007) would your company require to develop water heaters (EF ≥0.68, or condensing) meeting this NO_x requirement?	3 months 6 months 1 year	***Insufficient responses***

	How much will Rule 1121 compliance add to the manufacturing cost of an EF ≥0.68 water heater?	1. ________% **2. Decline to State**	**2. Decline to State**
	How much will Rule 1121 compliance add to the manufacturing cost of an EF ≥0.80 water heater?	1. ________% **2. Decline to State**	**2. Decline to State**
16	How interested are you in prototype R&D funding for developing a Rule 1121 compliant water heater?	**Not interested** Interested Very interested	**(+)* 1. Not interested** ***(+) indicates more interest***
17	When is your company planning to release one or more residential water heaters that meet Rule 1121?	1st Quarter 2007 **3rd Quarter 2007** 1st Quarter 2008 Other No plans Decline to State	**3rd Quarter 2007**
18	What will be the EF level of your initial Rule 1121-compliant 40 gallon unit?	1. 0.594 **2. 0.60 – 0.63** 3. 0.64 – 0.66 4. 0.67 – 0.69 5. Above 0.70 6. Decline to State	**2. 0.60 – 0.63**
19	If external electrical power is required, what voltage will be needed?	24 volt 110 volt Other **Decline to State** Not Applicable	**4. Decline to State**
20	Will venting requirements of the Rule 1121 model differ from existing units?	1. Yes **2. No** 3. Decline to State	**2. No**
21	Other Comments, Questions, or Concerns?	***In view of the desire to expand this project beyond California, it may be appropriate to consider an option for models that do not comply with Rule 1121.***	